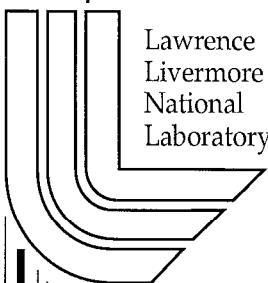


# The DARHT-II DC Final Focus Solenoid

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*U.S. Department of Energy*



**March 6, 2000**



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## The DARHT-II DC Final Focus Solenoid

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### 1. Introduction

The baseline DARHT2 external beam uses a pulsed solenoid final focus lens. The design of this lens was presented at TOS2<sup>1</sup> and has been considered as the final focus lens in all of the Livermore beamlines for DARHT2. In this note, we consider a new alternative DC final focus solenoid. A crude comparison between the parameters of these two designs is given in table 1. The small spot size required by the radiography and the small drift distance available between the last magnetic focusing element and the final focus solenoid imposed by the close proximity between the DARHT 2 building and the DARHT 1 axis, implies a short focal length solenoid. This in turn requires that the final focus solenoid mount inside the re-entrant cavity of the containment vessel in order to accommodate the 0.9 meter conjugate, figure 1. The ID of this cavity is 13.88 inches (35.25 cm).

Table 1  
Comparison between the Pulsed and DC Final Focus Solenoids

Parameter	Pulsed Solenoid	DC Solenoid	Unit
OD	16.2	35.0	cm
ID	6.0	8.0	cm
Physical Length	5.0	37.0	cm
Magnetic Length	7.2	20.98	cm
Max Field	18.0	5.8-9.8	KGauss
Current	490	800-1500	Amperes
Power	0.17	9.5-33.2	kilowatts
Weight	17.4	469	pounds
Flat Top	2.0	$\infty$	msec.

Considering the paramount differences between the pulsed solenoid and the DC solenoid in performance, serviceability, power, weight, and size, clearly makes the pulsed magnet superior to the DC design, and the baseline design.

### 2. The Beamline

The DARHT 2 beamline is described in report RM-0026<sup>2</sup> and extends from the exit of the DARHT2 accelerator to either 1) the main tuning dump, or 2) the xray converter target before the DARHT1-DARHT2 firing point, figure 2. After the kicker quadrupole-septum, there are three Collins

<sup>1</sup> External Assessment on DARHT 2nd axis Technology Options Study, March 25-26, 1997.

<sup>2</sup> U4EA:WRK/darht2/head/newk/final/xx text "The DARHT II Beamline", Arthur C. Paul, March 2000.

quadrupoles to re-establish a round beam suitable for solenoid transport. The nominal beam diameter exiting the last of the Collins quadrupoles is 3.0 cm, figure 3. Only one magnetic element, solenoid S4, lies between the last Collins quadrupole and the final focus solenoid, Sff. This lens is used to adjust the system magnification. Proper choice of excitation of S4 and Sff allows a range of beam diameters on the x-ray converter target. We have selected an inner magnet radius of 4.0 cm as being compatible with the beam radius of 1.5 cm. An iron shield must be provided around the final focus coil to reduce the magnetic field on the target to less than a few hundred Gauss.

### 3. The Design

Having selected a 8 cm inner diameter, and constrained by the confinement vessel to a outer diameter of 35 cm, we attempt to make the DC final focus solenoid short. Short in this context means a length comparable to its diameter. Figure 4 shows the summary of the design with parameters given in table 2.

After several attempts, we determined that 7 cm of iron on the up and down stream ends of the winding, surrounded by a cylinder of 2.5 cm thick iron reduced the fringing fields to acceptable values at the location of the target. The conductor cross-sectional area gives a current density of approximately

$$10 \text{ Amperes/ mm}^2$$

at 1000 Amperes. This is a nominally desirable value. Operation at a higher current is possible with either a higher temperature rise or an increased water flow. Should key-stoning be a problem, the axial length of the lens would have to be slightly increased.

Table 2  
Summary of DC Solenoid

Parameter	Value	unit
Length	37.0	cm
Outer radius	17.5	cm
Inner radius	4.0	cm
Conductor	7/16" square hollow	inch
Water passage hole	1/4	inch
Conductor spacing	1.30	cm
Turns	136	8 X 17
Total winding length	7861	cm
Resistance	0.01476	Ohms
Current(nominal)	1000	Amperes
Voltage	14.76	Volts @ 1000 A
Power	14.76	KW @ 1000 A
Weight copper	141	pounds
Weight iron	328	pounds
Weight total	469	pounds

The data for the POISSON code group<sup>3</sup> is given in table 3. Automesh generates the mesh for the lattice code, which sets up the coupling coefficients for the poisson code, which solves Poissons equation for the vector potential. Tekplot produces the plots shown in figures 5, 6, and 7.

<sup>3</sup> "Reference Manual for the POISSON/SUPERFISH group of codes", Los Alamos Accelerator code Group, LA-UR-87-126. The codes used are: automesh, lattice, poisson, tekplot.

Table 3  
Automesh, Poisson, and Tekplot data

<b>Automesh</b>
*sff 02/16/00 data in cm. 13.88" design, WRK/darht2/beamline/sff/coil4
*1 1.000 *4 0.5 0.5 *22 3 *23 50.0 0. *27 60.0 0 *31 1 stop
*21 0 1 0 0 stop
0. 0.
0. 60.
50. 60.
50. 0.
0. 0. continue
*18 1 *2 -68000.0 stop -- coil amperes
4.0 0.
4.0 11.05
14.4 11.05
14.4 0.
4.0 0. continue
*18 2 stop ---- new region iron
15.0 0.
15.0 11.5
4.0 11.5
4.0 18.5
17.5 18.5
17.5 0.
15.0 0. continue
<b>Poisson</b>
0 dump
*6 0
*30 1500
*42 1 1 1 61
*54 0 0 0 60.0
*85 1.0e-6 1.0e-6
stop
-1 dump
<b>Tekplot</b>
0 0 0 s
s
0 1 0
s
1 0 20 s
s
-1 s

Figures 5 and 7 show the geometry and flux lines generated by the Poisson group of codes. The magnetic field profile is given in figure 8 for excitations of 800 to 1500 Amperes in 100 Amperes steps. The peak field and effective magnetic length,  $L_m$  for these field values are given in table 4. The magnetic length is related to the solenoid focusing power by

$$L_m = \frac{\int B^2(z)dz}{B_0^2}$$

where  $B_0$  is the central, peak field.

Table 4  
Field and effective length

Current Amperes	Field Gauss	Length cm
800	5496.9	20.989
900	6088.0	20.987
1000	6652.8	20.983
1100	7194.1	20.981
1200	7713.5	20.977
1300	8225.2	20.973
1400	8734.8	20.971
1500	9242.9	20.969

The constancy of the length vs excitation is indicative of no saturation in the iron.

#### 4. Basic Optics

The transport code<sup>4</sup> has been used to evaluate the first order beam optics of both the pulse and DC final focus solenoids. Higher order aberrations will be evaluated later in this report. Basically, two solenoids are used, solenoids S4 and the final focus solenoid Sff, to adjust the total system magnification at a fixed target distance. Table 5 gives the transport data. The pulsed lens focuses 10.0 cm pass the lens exit with a field of 17.9 kG, the DC magnet focuses 12.707 cm pass the magnetic lens exit with a field of 6.688 kG (1000 Amperes). This focus position is 4.707 cm pass the physical exit of the lens.

Figures 9, 10, and 11 show figures 9, 10, and 11.

---

<sup>4</sup> "TRANSPORT, An Ion Optic Program LBL Version", Arthur C. Paul, LBL-2697, February 1975

Table 5  
Transport data

03/09/00
1
DC final focus solenoid optics
0
13 2.1
15 11 MeV/C 0.001
16 3 1
16 29 -1
24 0 6 6
1 1.5 2 1.5 2 0 0 20.5044
12 0r15
26 0.01 2000
3 0.55
6 7 5 19
19 0.25 0 s4
3 0.5
3 0.5
6 7 4 19
19 0.210 6.6884 sff
3 0.12707
13 1
3 0.1
73
pulsed final focus solenoid optics
0
13 2.1
15 11 MeV/C 0.001
16 3 1
16 29 -1
24 0 6 6
1 1.5 2 1.5 2 0 0 20.5044
12 0r15
26 0.01 2000
3 0.55
6 7 5 19
19 0.25 0 s4
3 0.5
3 0.5
6 7 3 19
19 0.05 17.94 sff
3 0.1
13 1
3 0.1
73
73

## 5. Excitation

The field along the axis of the solenoid has been calculated for 800 to 1500 Amperes. The peak field at these excitations can be calculated by a polynomial fit. Equations 5.1, 5.2 and 5.3 give the second, third and fourth order fits to the peak solenoid field. These equations give  $B_o$  at the center of the solenoid in Gauss as a function of the excitation current in Amperes.

$$B_o(I) = 4.15 + 7.6540 I - 0.0010096 I^2 \quad 5.1$$

fits the excitation curve with a standard deviation of 5.45 Gauss over the range of 0 to 1500 Amperes.

$$B_o(I) = -0.29 + 8.0897 I - 0.0017602 I^2 + 3.1488 \times 10^{-7} I^3 \quad 5.2$$

fits the excitation curve with a standard deviation of 2.10 Gauss.

$$B_o(I) = 0.08 + 6.8878 I + 0.0014624 I^2 - 2.4964 \times 10^{-6} I^3 + 7.9966 \times 10^{-10} I^4 \quad 5.3$$

fits the excitation curve with a standard deviation of 0.55 Gauss.

At 1000 Amperes, equation 5.2 terms are  $8089.7 - 1760.2 + 314.88 = 6644.4$  while equation 5.3 terms are  $6887.8 + 1462.4 - 2496.4 + 799.66 = 6653.5$ . The cancellation between significant terms such that all three  $I^n$  terms of equation 5.2 and all four  $I^n$  terms of equation 5.3 are required is characteristic of situation were there is significant curvature as with the shape of the  $B(i)$  curve of figure 12. Figure 12a, 12b, and 12c show the 2nd, 3rd, and 4th order fits.

## 6. Field Profile

The longitudinal magnetic field is well fit by a eighth order reciprocal polynomial, equation ??.

$$B(z) = \frac{B_o(I)}{1 + b(z/a)^2 + c(z/a)^4 + d(z/a)^6 + e(z/a)^8} \quad 6.1$$

The standard deviation over the range of  $z = \pm 60$  cm is 2.29 Gauss. The characteristic length of this equation is parameter  $a = 14.688$  cm. The magnetic length is 20.98 cm independent of peak excitation. The central field value of  $B_o(I)$  is given by one of the excitation equations 5.1 - 5.3.  $B$  is in Gauss and  $z$  is the longitudinal distance measured from the center of the solenoid in cm. The fitting parameters are

a	14.688 cm
b	0.23705
c	0.074556
d	0.81432
e	1.7744

Figure 13 shows the Poisson data points and the fitted curve, equation 6.1. Figure 14 gives the difference between the Poisson data points and the points generated by the fitting.

## 7. The Trajectory Code

Program to calculate orbits in a given magnetic field in polar or rectangular coordinates simultaneously integrating the differential equations for the first order ion optic matrix elements.<sup>5</sup> This code has

<sup>5</sup> "TRAJECTORY an Orbit and Ion Optic Matrix Program for the 184-inch Cyclotron", A.C.Paul, UCRL-19407, September 1969.

been modified now to include axial symmetry in order to accommodate solenoid focusing. With this geometry, the magnetic field along the axis of rotational symmetry is given as a function of axial distance. The transverse field components are calculated from a Taylor series expansion about the axis satisfying Maxwells equations. The data for evaluating the final focus solenoid is given in table 10.

The starting conditions for the orbits of the TRAJ code simulations were generated from the TRANSPORT code using the "ellipse" option to generate a table of points on the bounding phase space ellipse for the beam parameters of interest, here, a 1.5 cm radius beam with 3.0 cm-mr emittance, figure 15. These particles were then numerically integrated through the field free drift leading up to the solenoid lens and through that lens, pass the image point, figures 16, and 17. The region around the image has been expanded in figures 18, 19, 20, and 21.

## 8. Aberrations

The first order calculations used in the beamline designs do not address the effects of chromatic and spherical aberrations in the final focus lens. The actual beam radius is given as the quadrature sum of three terms representing the effects of the finite transverse phase space, spherical aberration, and chromatic aberration.

$$r^2 = \left[ \frac{\epsilon f}{R_o} \right]^2 + \left[ \frac{1}{4f} c_{sa} R_o^3 \right]^2 + \left[ 2 \frac{\delta\gamma}{\gamma} R_o \right]^2 . \quad X.1$$

Here  $R_o$  is the initial beam radius entering the lens,  $f$  the lens focal length,  $\epsilon$  the beam emittance,  $c_{sa}$  the coefficient of spherical aberration, and  $\gamma$  the usual relativistic factor.

The transport code is used to generate the first order beam size and focal location, given in columns 3 and 4, tables 6, 7, 8, and 9, figure 11. Figure 15 shows the transverse phase space for beam radius of 1, 1.5, 2, and 3 cm. The inner radius of the magnet is 4 cm, so the 2 and 3 cm radius beams should show considerable spherical aberration. The "TRAJ" code is used to numerically integrate trajectories through the final solenoid magnetic field. The field components off-axis are developed by a Taylor series expansion of the axial magnetic field. The TRAJ code allows the user to select how many terms should be used in developing the off axis field components. These calculations used fifth order field expansions. Figure 17 shows 90 trajectories of a 2 cm radius beam. Here 30 points were generated on the bounding transverse phase space ellipse, figure 15, at each of three energies,  $E_o$ ,  $E_o - 0.5\%$ , and  $E_o + 0.5\%$ . The axial region around the minimum is expanded in figures 18, 19, 20, and 21 for beams of initial radius of 1, 1.5, 2, and 3 cm.

The nominal design beam diameter on the xray converter target is 0.130 cm, 0.065 cm radius. The solid curves of figure 22 show the transport code result at the target for each of the radius values considered. The dashed curves are the result from the TRAJ code with  $\delta E/E = 0$  giving only the size based on the beam emittance and spherical aberration of the final lens. Figures 23, 24, 25, and 26 give similar curves for  $\pm 0.5\%$ ,  $\pm 1.0\%$ ,  $\pm 1.5\%$ , and  $\pm 2.0\% \delta E/E$  giving the combination of spherical and chromatic aberrations.

Table 6  
Initial beam radius 1.0 cm

I(a)	B(kG)	z1(cm) tran3	r(cm) 1st order	r(cm) dE/E=0%	r(cm) dE/E=0.5%	r(cm) dE/E=1.0%	r(cm) dE/E=1.5%	r(cm) dE/E=2.0%
800	5.49690	0.22595	0.10110	0.10110	0.10490	0.10315	0.10490	0.10756
900	6.08800	0.16958	0.08440	0.08489	0.08567	0.08727	0.08955	0.09247
1000	6.65280	0.12880	0.07270	0.07349	0.07422	0.07585	0.07831	0.08119
1100	7.19410	0.09808	0.06400	0.06499	0.06586	0.06768	0.06990	0.07345
1200	7.71350	0.07418	0.05750	0.05867	0.05985	0.06196	0.06372	0.06825
1300	8.22520	0.05462	0.05230	0.05381	0.05471	0.05706	0.05887	0.06490
1400	8.73480	0.03814	0.04820	0.05015	0.05126	0.05237	0.05557	0.05963
1500	9.24290	0.02397	0.04480	0.04912	0.05233	0.05373	0.05437	0.06060

Table 7  
Initial beam radius 1.5 cm

I(a)	B(kG)	z1(cm) tran3	r(cm) 1st order	r(cm) dE/E=0%	r(cm) dE/E=0.5%	r(cm) dE/E=1.0%	r(cm) dE/E=1.5%	r(cm) dE/E=2.0%
800	5.49690	0.22332	0.06710	0.06751	0.06901	0.07358	0.07956	0.08713
900	6.08800	0.16744	0.05620	0.05682	0.05899	0.06390	0.07031	0.07888
1000	6.65280	0.12707	0.04840	0.04914	0.05114	0.05578	0.06373	0.07178
1100	7.19410	0.09666	0.04270	0.04358	0.04709	0.05257	0.05867	0.06966
1200	7.71350	0.07298	0.03840	0.03959	0.04163	0.04703	0.05782	0.06376
1300	8.22520	0.05359	0.03500	0.03598	0.04107	0.04789	0.05268	0.06511
1400	8.73480	0.03723	0.03220	0.03353	0.03713	0.04362	0.05428	0.06242
1500	9.24290	0.02318	0.03000	0.03623	0.03894	0.04211	0.05384	0.05866

Table 8  
Initial beam radius 2.0 cm

I(a)	B(kG)	z1(cm) tran3	r(cm) 1st order	r(cm) dE/E=0%	r(cm) dE/E=0.5%	r(cm) dE/E=1.0%	r(cm) dE/E=1.5%	r(cm) dE/E=2.0%
800	5.49690	0.22254	0.05020	0.05082	0.05658	0.06554	0.07766	0.08980
900	6.08800	0.16685	0.04210	0.04255	0.04861	0.06134	0.07204	0.08574
1000	6.65280	0.12661	0.03630	0.03752	0.04695	0.05510	0.06827	0.08002
1100	7.19410	0.09629	0.03200	0.03611	0.04210	0.05523	0.06464	0.08014
1200	7.71350	0.07268	0.02880	0.03230	0.04313	0.05450	0.06646	0.08146
1300	8.22520	0.05334	0.02620	0.03143	0.04298	0.05149	0.06359	0.07839
1400	8.73480	0.03702	0.02410	0.03291	0.03984	0.04846	0.06109	0.07572
1500	9.24290	0.02299	0.02250	0.03611	0.03910	0.04818	0.05898	0.07346

Table 9  
Initial beam radius 3.0 cm

I(a)	B(kG)	z1(cm) tran3	r(cm) 1st order	r(cm) dE/E=0%	r(cm) dE/E=0.5%	r(cm) dE/E=1.0%	r(cm) dE/E=1.5%	r(cm) dE/E=2.0%
800	5.49690	0.22201	0.03340	0.04921	0.06710	0.08763	0.10605	0.12648
900	6.08800	0.16648	0.02800	0.05122	0.06422	0.08463	0.10157	0.12665
1000	6.65280	0.12633	0.02410	0.05093	0.06277	0.08324	0.09824	0.12595
1100	7.19410	0.09607	0.02130	0.05069	0.06259	0.08315	0.09850	0.12327
1200	7.71350	0.07251	0.01920	0.05054	0.06251	0.08403	0.09862	0.12259
1300	8.22520	0.05320	0.01750	0.05171	0.06300	0.08566	0.09959	0.12088
1400	8.73480	0.03689	0.01610	0.05297	0.06617	0.08972	0.10096	0.12232
1500	9.24290	0.02288	0.01500	0.05425	0.06616	0.08980	0.10272	0.12321

Table 10  
Trajectory code data for final lens.

---

```

#  

#TRAJ data generated by xx gen
4 6 1.0 0 4 # read field from tape unit 4
-60.0 60.0 1.0
3 2 0.000511 # restmass GeV
3 5 4000      # max number of steps
3 7 0          # turn off/on (0/1) matrix
3 8 1          # punch orbit output to tape 8
3 10 0.25     # rk step size in cm
3 13 2.9979e-7 # distance in cm
# 3 14 1      # matrix unit
3 16 0          # suppress orbit plots
3 18 1          # inorbt - orbit input type
3 20 3          # Third order field expansion
3 20 5          # fifth order field expansion
#
#
# 2 x(cm)    px      y(cm)    py z pz E(GeV)  ds smax sout
# ----- -----
2 1.50000  0.00000 -55.0 1. 0. 0. -0.01990 1. 101. 1. 101. 200.
2 1.46490  0.00043 -55.0 1. 0. 0. -0.01990 1. 101. 1. 101. 200.
2 1.36140  0.00084 -55.0 1. 0. 0. -0.01990 1. 101. 1. 101. 200.
2 1.19410  0.00121 -55.0 1. 0. 0. -0.01990 1. 101. 1. 101. 200.
2 0.97110  0.00152 -55.0 1. 0. 0. -0.01990 1. 101. 1. 101. 200.
2 0.70260  0.00177 -55.0 1. 0. 0. -0.01990 1. 101. 1. 101. 200.
2 0.40130  0.00193 -55.0 1. 0. 0. -0.01990 1. 101. 1. 101. 200.
2 0.08120  0.00200 -55.0 1. 0. 0. -0.01990 1. 101. 1. 101. 200.
2 -0.24270 0.00197 -55.0 1. 0. 0. -0.01990 1. 101. 1. 101. 200.
2 -0.55520 0.00186 -55.0 1. 0. 0. -0.01990 1. 101. 1. 101. 200.
2 -0.84180 0.00166 -55.0 1. 0. 0. -0.01990 1. 101. 1. 101. 200.
2 -1.08900 0.00138 -55.0 1. 0. 0. -0.01990 1. 101. 1. 101. 200.
2 -1.28530 0.00103 -55.0 1. 0. 0. -0.01990 1. 101. 1. 101. 200.
2 -1.42150 0.00064 -55.0 1. 0. 0. -0.01990 1. 101. 1. 101. 200.
2 -1.49120 0.00022 -55.0 1. 0. 0. -0.01990 1. 101. 1. 101. 200.
2 -1.49120 -0.00022 -55.0 1. 0. 0. -0.01990 1. 101. 1. 101. 200.
2 -1.42150 -0.00064 -55.0 1. 0. 0. -0.01990 1. 101. 1. 101. 200.
2 -1.28530 -0.00103 -55.0 1. 0. 0. -0.01990 1. 101. 1. 101. 200.
2 -1.08900 -0.00138 -55.0 1. 0. 0. -0.01990 1. 101. 1. 101. 200.
2 -0.84180 -0.00166 -55.0 1. 0. 0. -0.01990 1. 101. 1. 101. 200.
2 -0.55520 -0.00186 -55.0 1. 0. 0. -0.01990 1. 101. 1. 101. 200.
2 -0.24270 -0.00197 -55.0 1. 0. 0. -0.01990 1. 101. 1. 101. 200.
2 0.08120 -0.00200 -55.0 1. 0. 0. -0.01990 1. 101. 1. 101. 200.
2 0.40130 -0.00193 -55.0 1. 0. 0. -0.01990 1. 101. 1. 101. 200.
2 0.70260 -0.00177 -55.0 1. 0. 0. -0.01990 1. 101. 1. 101. 200.
2 0.97110 -0.00152 -55.0 1. 0. 0. -0.01990 1. 101. 1. 101. 200.
2 1.19410 -0.00121 -55.0 1. 0. 0. -0.01990 1. 101. 1. 101. 200.
2 1.36140 -0.00084 -55.0 1. 0. 0. -0.01990 1. 101. 1. 101. 200.
2 1.46490 -0.00043 -55.0 1. 0. 0. -0.01990 1. 101. 1. 101. 200.
2 1.50000  0.00000 -55.0 1. 0. 0. -0.02000 1. 101. 1. 101. 200.
#
2 1.50000  0.00000 -55.0 1. 0. 0. -0.02000 1. 101. 1. 101. 200.

```

---

2 1.46490 0.00043 -55.0 1. 0. 0. -0.02000 1. 101. 1. 101. 200.  
2 1.36140 0.00084 -55.0 1. 0. 0. -0.02000 1. 101. 1. 101. 200.  
2 1.19410 0.00121 -55.0 1. 0. 0. -0.02000 1. 101. 1. 101. 200.  
2 0.97110 0.00152 -55.0 1. 0. 0. -0.02000 1. 101. 1. 101. 200.  
2 0.70260 0.00177 -55.0 1. 0. 0. -0.02000 1. 101. 1. 101. 200.  
2 0.40130 0.00193 -55.0 1. 0. 0. -0.02000 1. 101. 1. 101. 200.  
2 0.08120 0.00200 -55.0 1. 0. 0. -0.02000 1. 101. 1. 101. 200.  
2 -0.24270 0.00197 -55.0 1. 0. 0. -0.02000 1. 101. 1. 101. 200.  
2 -0.55520 0.00186 -55.0 1. 0. 0. -0.02000 1. 101. 1. 101. 200.  
2 -0.84180 0.00166 -55.0 1. 0. 0. -0.02000 1. 101. 1. 101. 200.  
2 -1.08900 0.00138 -55.0 1. 0. 0. -0.02000 1. 101. 1. 101. 200.  
2 -1.28530 0.00103 -55.0 1. 0. 0. -0.02000 1. 101. 1. 101. 200.  
2 -1.42150 0.00064 -55.0 1. 0. 0. -0.02000 1. 101. 1. 101. 200.  
2 -1.49120 0.00022 -55.0 1. 0. 0. -0.02000 1. 101. 1. 101. 200.  
2 -1.49120 -0.00022 -55.0 1. 0. 0. -0.02000 1. 101. 1. 101. 200.  
2 -1.42150 -0.00064 -55.0 1. 0. 0. -0.02000 1. 101. 1. 101. 200.  
2 -1.28530 -0.00103 -55.0 1. 0. 0. -0.02000 1. 101. 1. 101. 200.  
2 -1.08900 -0.00138 -55.0 1. 0. 0. -0.02000 1. 101. 1. 101. 200.  
2 -0.84180 -0.00166 -55.0 1. 0. 0. -0.02000 1. 101. 1. 101. 200.  
2 -0.55520 -0.00186 -55.0 1. 0. 0. -0.02000 1. 101. 1. 101. 200.  
2 -0.24270 -0.00197 -55.0 1. 0. 0. -0.02000 1. 101. 1. 101. 200.  
2 0.08120 -0.00200 -55.0 1. 0. 0. -0.02000 1. 101. 1. 101. 200.  
2 0.40130 -0.00193 -55.0 1. 0. 0. -0.02000 1. 101. 1. 101. 200.  
2 0.70260 -0.00177 -55.0 1. 0. 0. -0.02000 1. 101. 1. 101. 200.  
2 0.97110 -0.00152 -55.0 1. 0. 0. -0.02000 1. 101. 1. 101. 200.  
2 1.19410 -0.00121 -55.0 1. 0. 0. -0.02000 1. 101. 1. 101. 200.  
2 1.36140 -0.00084 -55.0 1. 0. 0. -0.02000 1. 101. 1. 101. 200.  
2 1.46490 -0.00043 -55.0 1. 0. 0. -0.02000 1. 101. 1. 101. 200.  
2 1.50000 0.00000 -55.0 1. 0. 0. -0.02000 1. 101. 1. 101. 200.  
#  
2 1.50000 0.00000 -55.0 1. 0. 0. 0. -0.02010 1. 101. 1. 101. 200.  
2 1.46490 0.00043 -55.0 1. 0. 0. -0.02010 1. 101. 1. 101. 200.  
2 1.36140 0.00084 -55.0 1. 0. 0. -0.02010 1. 101. 1. 101. 200.  
2 1.19410 0.00121 -55.0 1. 0. 0. -0.02010 1. 101. 1. 101. 200.  
2 0.97110 0.00152 -55.0 1. 0. 0. -0.02010 1. 101. 1. 101. 200.  
2 0.70260 0.00177 -55.0 1. 0. 0. -0.02010 1. 101. 1. 101. 200.  
2 0.40130 0.00193 -55.0 1. 0. 0. -0.02010 1. 101. 1. 101. 200.  
2 0.08120 0.00200 -55.0 1. 0. 0. -0.02010 1. 101. 1. 101. 200.  
2 -0.24270 0.00197 -55.0 1. 0. 0. -0.02010 1. 101. 1. 101. 200.  
2 -0.55520 0.00186 -55.0 1. 0. 0. -0.02010 1. 101. 1. 101. 200.  
2 -0.84180 0.00166 -55.0 1. 0. 0. -0.02010 1. 101. 1. 101. 200.  
2 -1.08900 0.00138 -55.0 1. 0. 0. -0.02010 1. 101. 1. 101. 200.  
2 -1.28530 0.00103 -55.0 1. 0. 0. -0.02010 1. 101. 1. 101. 200.  
2 -1.42150 0.00064 -55.0 1. 0. 0. -0.02010 1. 101. 1. 101. 200.  
2 -1.49120 0.00022 -55.0 1. 0. 0. -0.02010 1. 101. 1. 101. 200.  
2 -1.49120 -0.00022 -55.0 1. 0. 0. -0.02010 1. 101. 1. 101. 200.  
2 -1.42150 -0.00064 -55.0 1. 0. 0. -0.02010 1. 101. 1. 101. 200.  
2 -1.28530 -0.00103 -55.0 1. 0. 0. -0.02010 1. 101. 1. 101. 200.  
2 -1.08900 -0.00138 -55.0 1. 0. 0. -0.02010 1. 101. 1. 101. 200.  
2 -0.84180 -0.00166 -55.0 1. 0. 0. -0.02010 1. 101. 1. 101. 200.  
2 -0.55520 -0.00186 -55.0 1. 0. 0. -0.02010 1. 101. 1. 101. 200.  
2 -0.24270 -0.00197 -55.0 1. 0. 0. -0.02010 1. 101. 1. 101. 200.  
2 0.08120 -0.00200 -55.0 1. 0. 0. -0.02010 1. 101. 1. 101. 200.  
2 0.40130 -0.00193 -55.0 1. 0. 0. -0.02010 1. 101. 1. 101. 200.

2 0.70260 -0.00177 -55.0 1. 0. 0. -0.02010 1. 101. 1. 101. 200.  
2 0.97110 -0.00152 -55.0 1. 0. 0. -0.02010 1. 101. 1. 101. 200.  
2 1.19410 -0.00121 -55.0 1. 0. 0. -0.02010 1. 101. 1. 101. 200.  
2 1.36140 -0.00084 -55.0 1. 0. 0. -0.02010 1. 101. 1. 101. 200.  
2 1.46490 -0.00043 -55.0 1. 0. 0. -0.02010 1. 101. 1. 101. 200.  
2 1.50000 0.00000 -55.0 1. 0. 0. -0.02010 1. 101. 1. 101. 200.  
20

- 
- FIGURE 1 The containment vessel showing the two conjugate points and re-entrant port into which the final focus solenoid must fit.
- FIGURE 2 DARHT-II beamline layout showing the magnetic components between the exit of the DARHT-II accelerator and the DARHT-I beamline. The large circle at centered at the DARHT-I DARHT-II intersection is 1.1 meters in radius. The 5'-2" shielding wall straddles the kicker quadrupole septum.
- FIGURE 3 Nominal beam profile of DARHT-II the design parameters matched to the accelerator. The beam exits the accelerator at 1.0 cm radius, and expands to match the kicker at 3.0 cm radius. This beam is rounded by quadrupoles QCH, QCV, and QCW to 1.5 cm radius for transport to the final focus solenoid.
- FIGURE 4 Summary of the DC final focus solenoid magnet design. Shown is the POISSON code data and a schematic of the iron shield and coil winding At 1000 Amperes, the magnet has a effective length of 20.98 cm and peak field of 6.65 kG. The magnet ID is 8.0 cm.
- FIGURE 5 The POISSON code group TEKPLOT output showing the coil and iron shield. The longitudinal axis is the axis of axial symmetry, points up and extends from the center of the winding to 60.0 cm. The radial axis extends to 50 cm through the center of the lens.
- FIGURE 6 The mesh generated by the POISSON code group AUTOMESH code.
- FIGURE 7 The flux lines generated by the POISSON code group codes at the nominal excitation of 1000 Amperes.
- FIGURE 8 Magnetic field profile at solenoid excitations of 800 to 1500 Amperes in 100 Ampere steps. The value of the peak field and magnetic length is tabulated for convenience.
- FIGURE 9 The transport first order beam envelop profile for nominal beam parameters of 20.0 MeV, 2000 Amperes, 3.0 cm-mr emittance. Solenoids S4 and Sff run at strengths 0, and 6.6884 kG. The target image is 0.12707 meters pass the magnetic exit of Sff.
- FIGURE 10 The transport first order beam envelop profile for the baseline final focus solenoid for nominal beam parameters. Solenoids S4 and Sff run at strengths of 0 and 17.94 kG.
- FIGURE 11 Focusing of the beam by the final focus solenoid Sff. The several beam traces are for excitations of 800, 900, ..., 1500 Amperes in steps of 100 Amperes.
- FIGURE 12 Excitation curves for final focus DC solenoid. A) fit by 2nd order polynomial, B) fit by 3rd order polynomial, C) fit by 4th order polynomial.

- FIGURE 13 Fit to the axial field profile at 1000 Amperes excitation. The shape is generated by a reciprocal eighth order polynomial, equation 6.1. The two vertical lines represent the extent of the magnetic length of the lens. The fitting polynomial is plotted as the curve, the cross (+) are the POISSON code calculated data points.
- FIGURE 14 Difference between the Poisson code calculated data points and those generated by the fitting equation. The two vertical lines delineate the magnetic length of the solenoid.
- FIGURE 15 Transverse phase space for beam radius of 1.0, 1.5, 2.0, and 3.0 cm and nominal parameters of 20 MeV, 3 cm-mr emittance. Points on these bounding ellipsoids are used by the Trajectory code to evaluate the chromatic and spherical aberrations.
- FIGURE 16 TRAJ code orbits for particle load along the x and y axes on a 0.25 cm grid. Orbit at  $+X = 1.5$  cm have an angular distribution of  $\pm 2.0$  mr. These orbits are defined with energies of 19.8, 20.0, and 20.2 MeV. Note that the orbits distributed along the Y axis at  $X=0$  rotate into the x plane as they pass through the focusing lens centered at  $Z=0$ . The thickening of the lines toward the right of the plot is the effect of the energy spread, dispersed by the chromatic aberration of the final lens.
- FIGURE 17 TRAJ code orbits distributed in the phase space shown in figure 15. Plotted here is the radius vs longitudinal position, with the final focus lens centered at  $Z=0$ , imaging the beam at about 23 cm. The phase space points are run at energies deviations of  $-0.5$ ,  $0$ ,  $+0.5\%$ .
- FIGURE 18 Expanded zone around image, for an initial beam radius of  $1.0 \text{ cm} \pm 0.5\% \text{ dE/E}$ . The image point is 24.07 cm.
- FIGURE 19 Expanded zone around image, for an initial beam radius of  $1.5 \text{ cm} \pm 0.5\% \text{ dE/E}$ . The image point is 23.85 cm.
- FIGURE 20 Expanded zone around image, for an initial beam radius of  $2.0 \text{ cm} \pm 0.5\% \text{ dE/E}$ . The image point is 23.58 cm.
- FIGURE 21 Expanded zone around image, for an initial beam radius of  $3.0 \text{ cm} \pm 0.5\% \text{ dE/E}$ . The image point is 23.12 cm. Note the shorting of the focal length with the larger initial beam loads.
- FIGURE 22 Summary of chromatic and spherical aberrations,  $0\% \text{ dE/E}$   
Initial particle loads of 1.0, 1.5, 2.0, and 3.0 cm, figure 15.
- FIGURE 23 Summary of chromatic and spherical aberrations,  $\pm 0.5\% \text{ dE/E}$   
Initial particle loads of 1.0, 1.5, 2.0, and 3.0 cm, figure 15.
- FIGURE 24 Summary of chromatic and spherical aberrations,  $\pm 1.0\% \text{ dE/E}$   
Initial particle loads of 1.0, 1.5, 2.0, and 3.0 cm, figure 15.

FIGURE 25      Summary of chromatic and spherical aberrations,  $\pm 1.5\%$  dE/E  
Initial particle loads of 1.0, 1.5, 2.0, and 3.0 cm, figure 15.

FIGURE 26      Summary of chromatic and spherical aberrations,  $\pm 2.0\%$  dE/E  
Initial particle loads of 1.0, 1.5, 2.0, and 3.0 cm, figure 15.

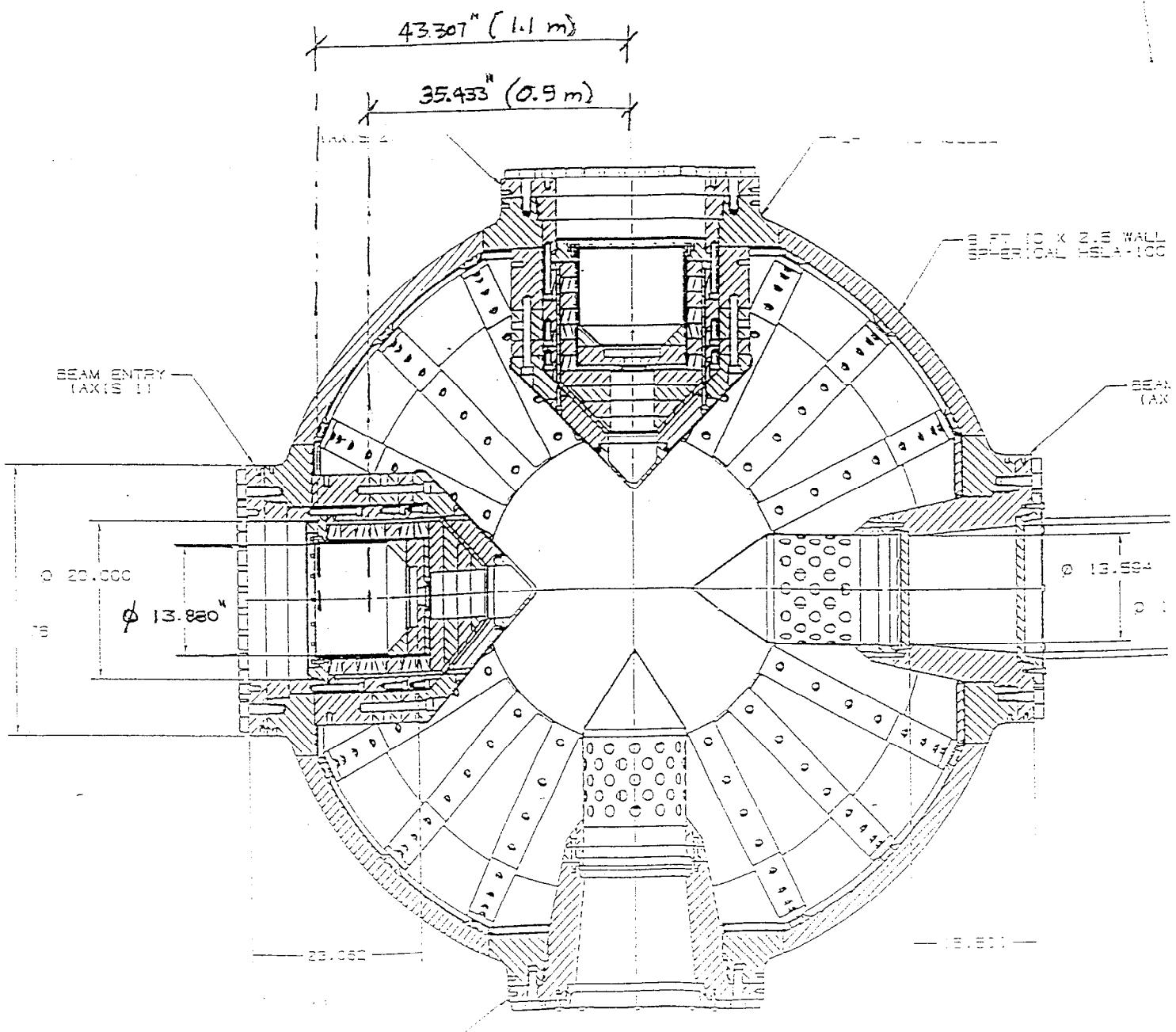
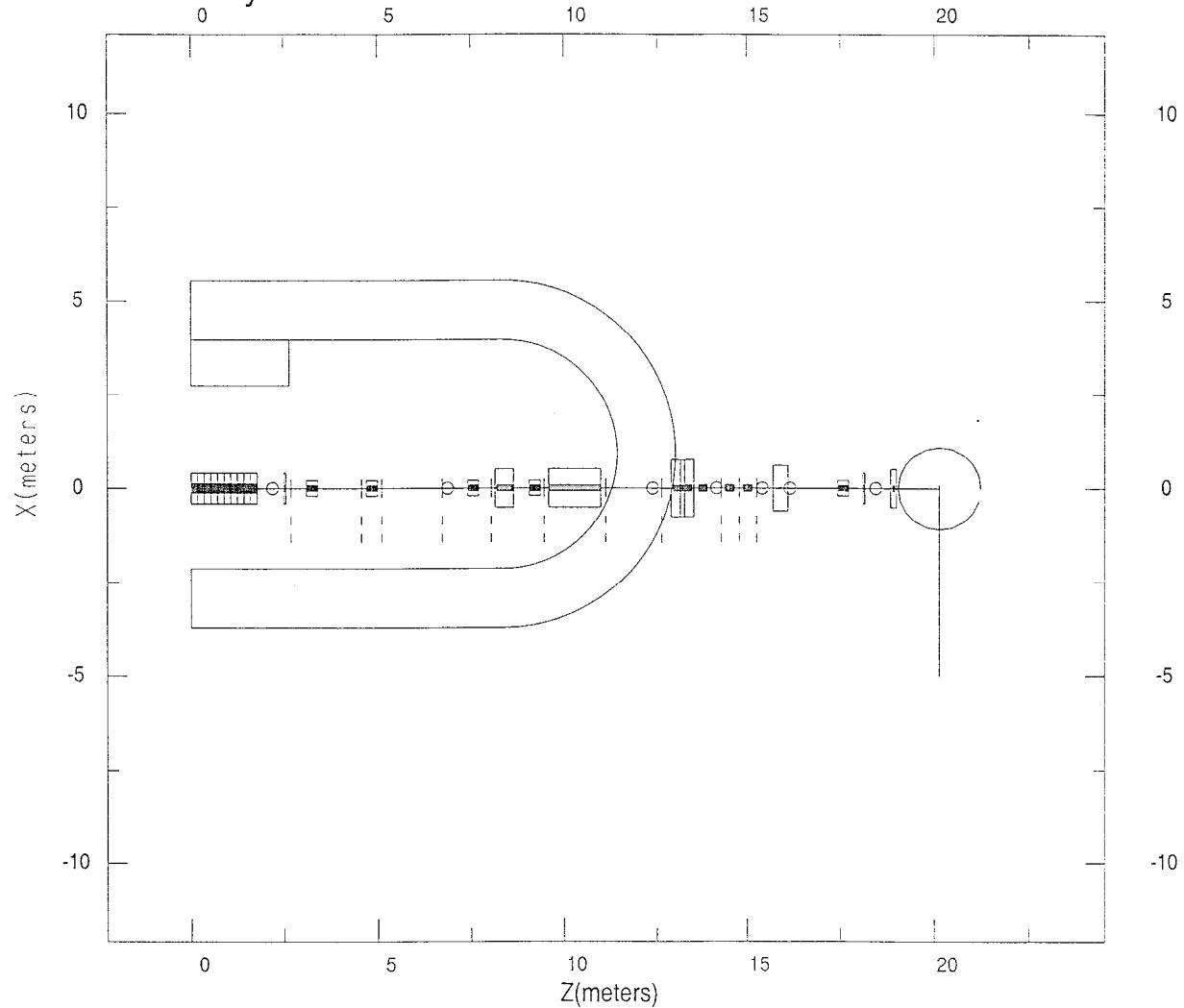


FIGURE 1 The containment vessel showing the two conjugate points and re-entrant port into which the final focus solenoid must fit.

12/13/99 Data from print 99-120555  
darht2 - final beamline ( $Z_e=60.2\text{ft}$ )  
Global Survey Coordinates

$P = 20.5044 \text{ MeV/C}$   
emit  $3.000 \quad 3.000 \text{ cm-mr}$



REG# 9  
RUN# 2  
PLOT: 4

/export/work/acpaul/darht2/beamline/final

data: data.darht2

RUN:0013Mar at 14:33:32

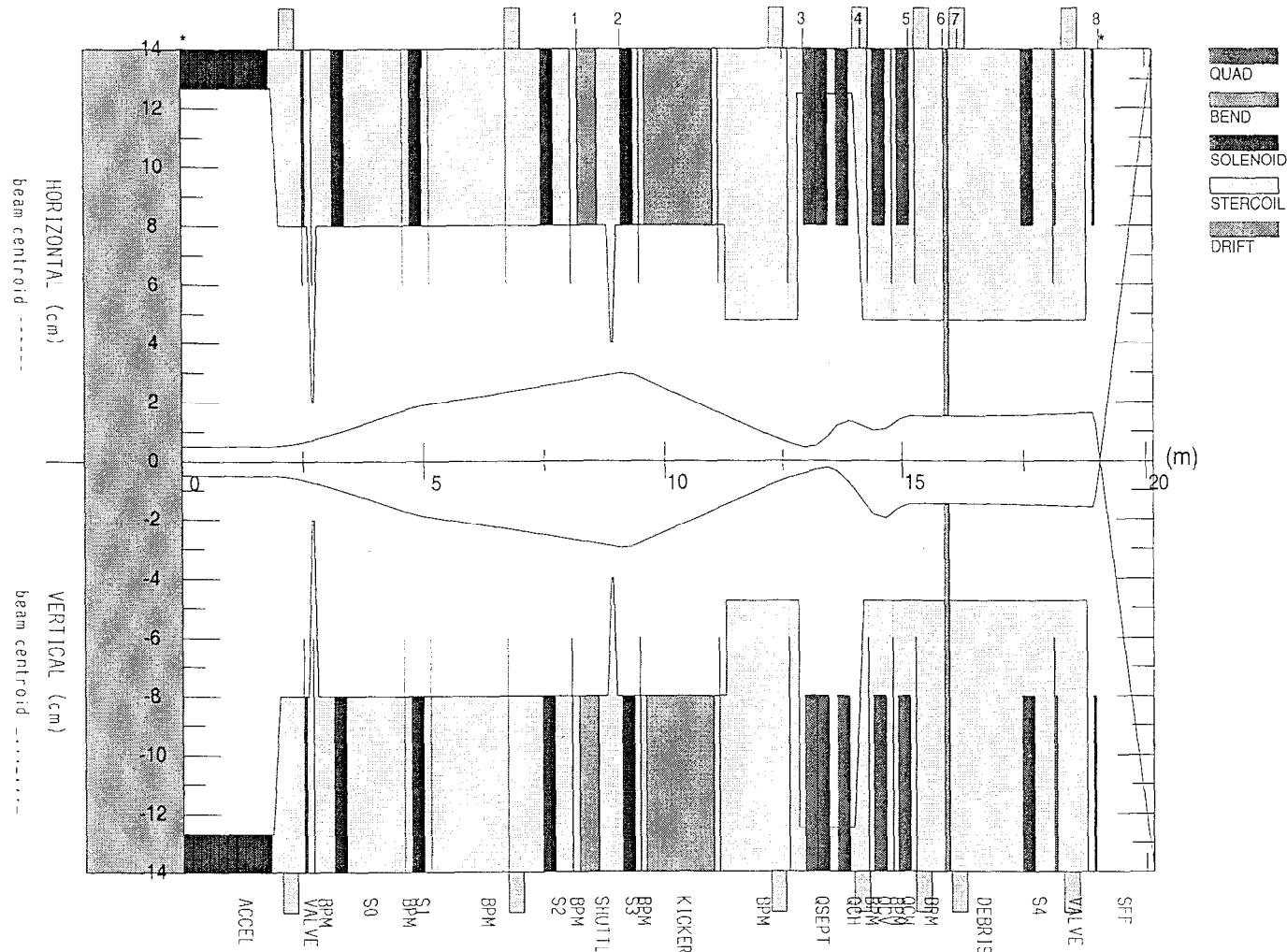
Figure 2) DARHT-II beamline layout showing the magnetic components between the exit of the DARHT-II accelerator and the DARHT-I beamline. The large circle centered at the DARHT-I DARHT-II intersections is 1.1 meters in radius. The 5'-2" shielding wall straddles the kicker quadrupole septum drift region.

line 4

12/13/99 Data from print 99-120555  
darht2 - final beamline ( $Z_e=60.2\text{ft}$ )

$P = 20.5044 \text{ MeV/C}$   
emit  $3.000 \quad 3.000 \text{ cm-mm}$

zrange: 0. 20.1452 m



REG#: 9  
RUN#: 2  
PLOT: 3

/export/work/acpaul/darht2/beamline/final

data: data.darht2

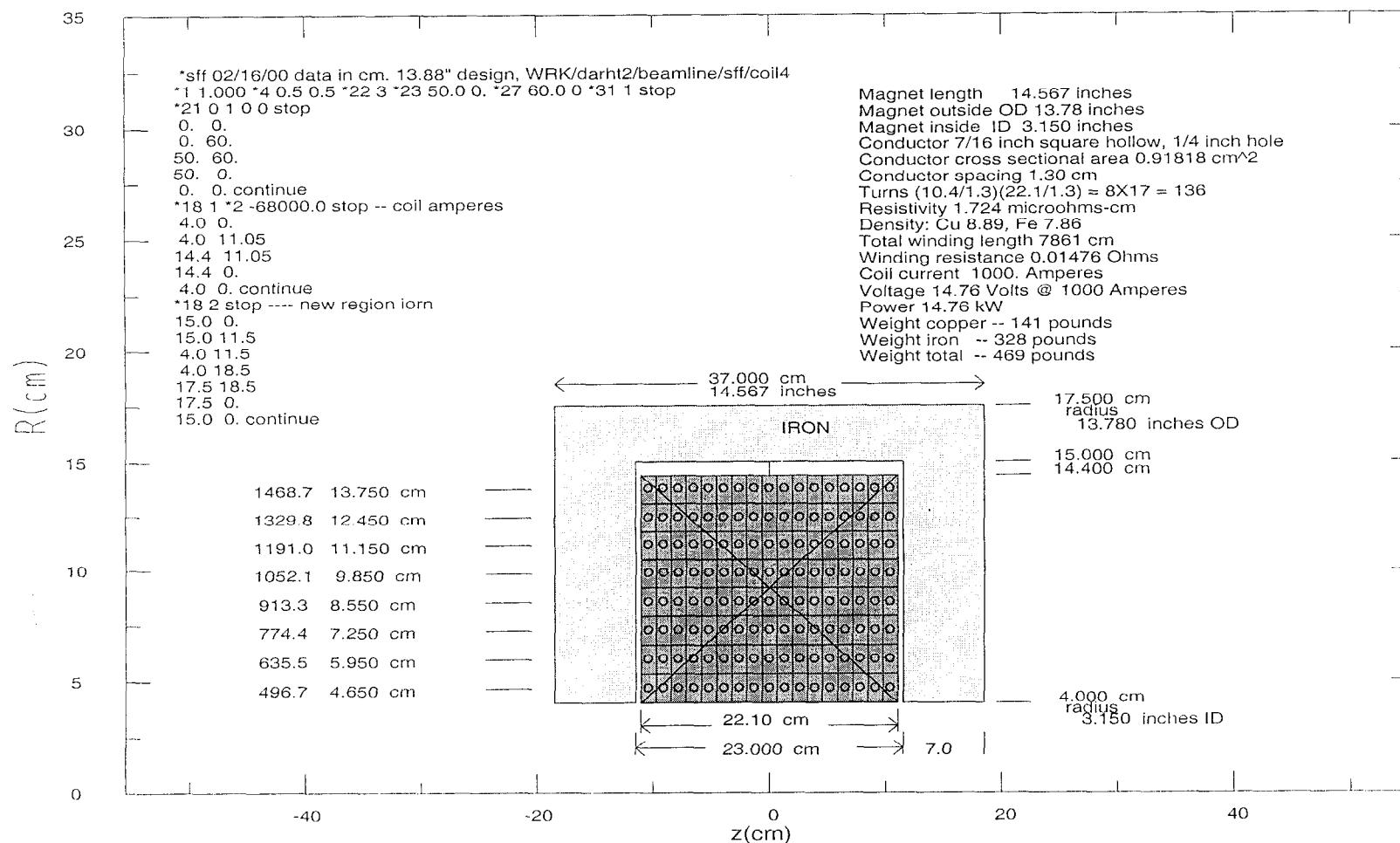
RUN:0013Mar at 14:33:32

Figure 3) Nominal beam profile of DARHT-II with design parameters matched to the accelerator. The beam exits the accelerator at a radius of 1.0 cm, and expands to match the kicker at 3.0 cm radius. This beam is rounded by quadrupoles QCH, QCV and QCW to 1.5 cm radius for transport to the final focus solenoid.  
line 4

# DARHT2 - DC FINAL FOCUS SOLENOID - Sff2

All dimensions in cm unless explicitly stated otherwise  
 automesh data (LLNL format) for Lattice-Poisson-Tekplot  
 Magnet fits inside the containment vessel re-entrance cavity

$B^2L = 9.2870e+08 \text{ G}^2\text{-cm} @ 1000 \text{ A}$   
 $B_0 = 6652.8 \text{ Gauss}$   
 $L_{mag} = 20.983 \text{ cm}$



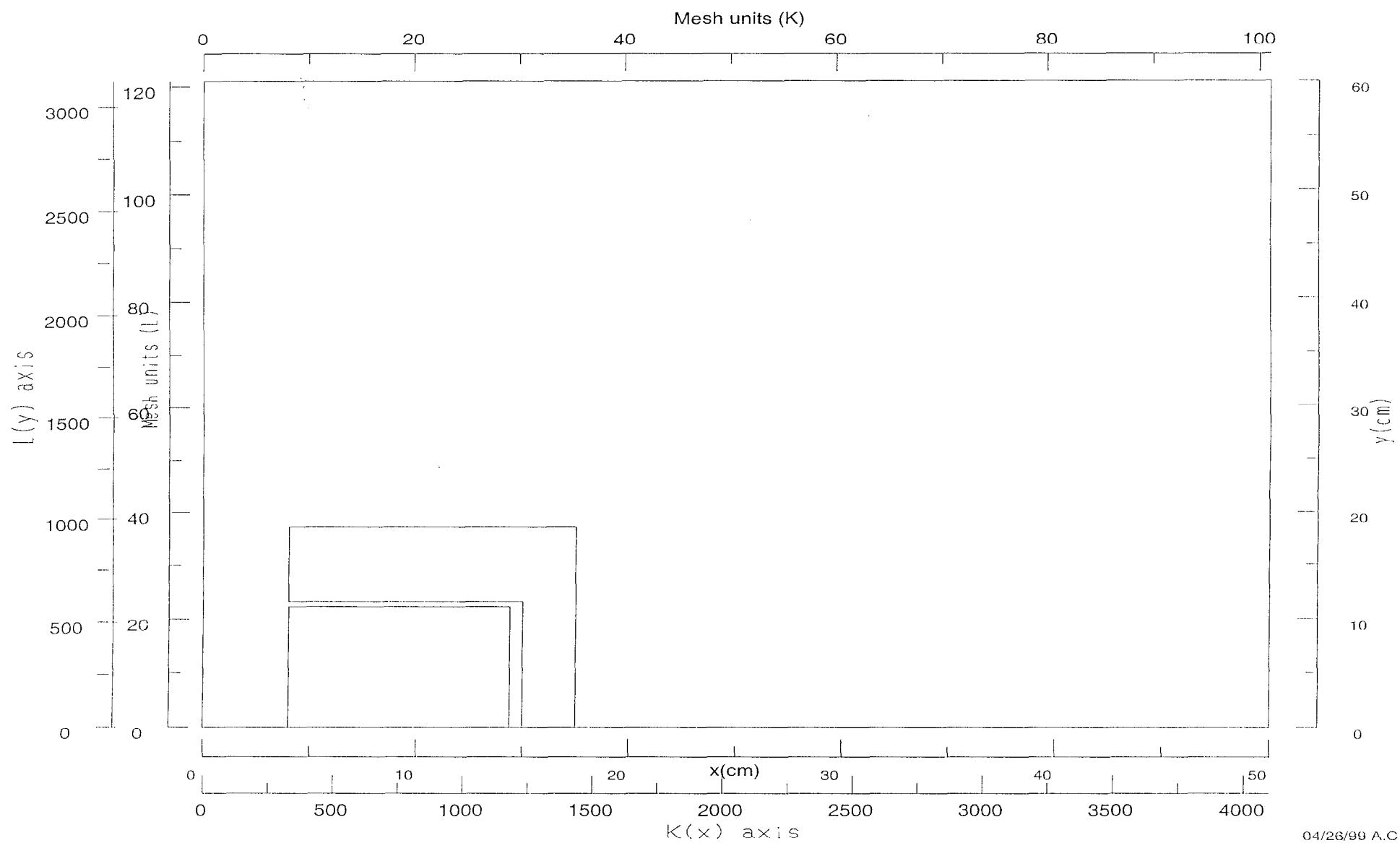
/export/work/acpaul/darht2/beamline/sff/coil4  
 data.auto

13-Mar-00

A.C.Paul  
 13-Mar-00

FIGURE 4) Summary of the DC final focus solenoid magnet design. Shown is the POISSON code data and a schematic of the iron shield and coil winding. At 1000 Amperes, the magnet has an effective length of 20.98 cm and a peak field of 6.65 kG. The magnet ID is 8.0 cm.  
 line 4

# POISSON LATTICE MESH PLOT



04/26/99 A.C.Paul

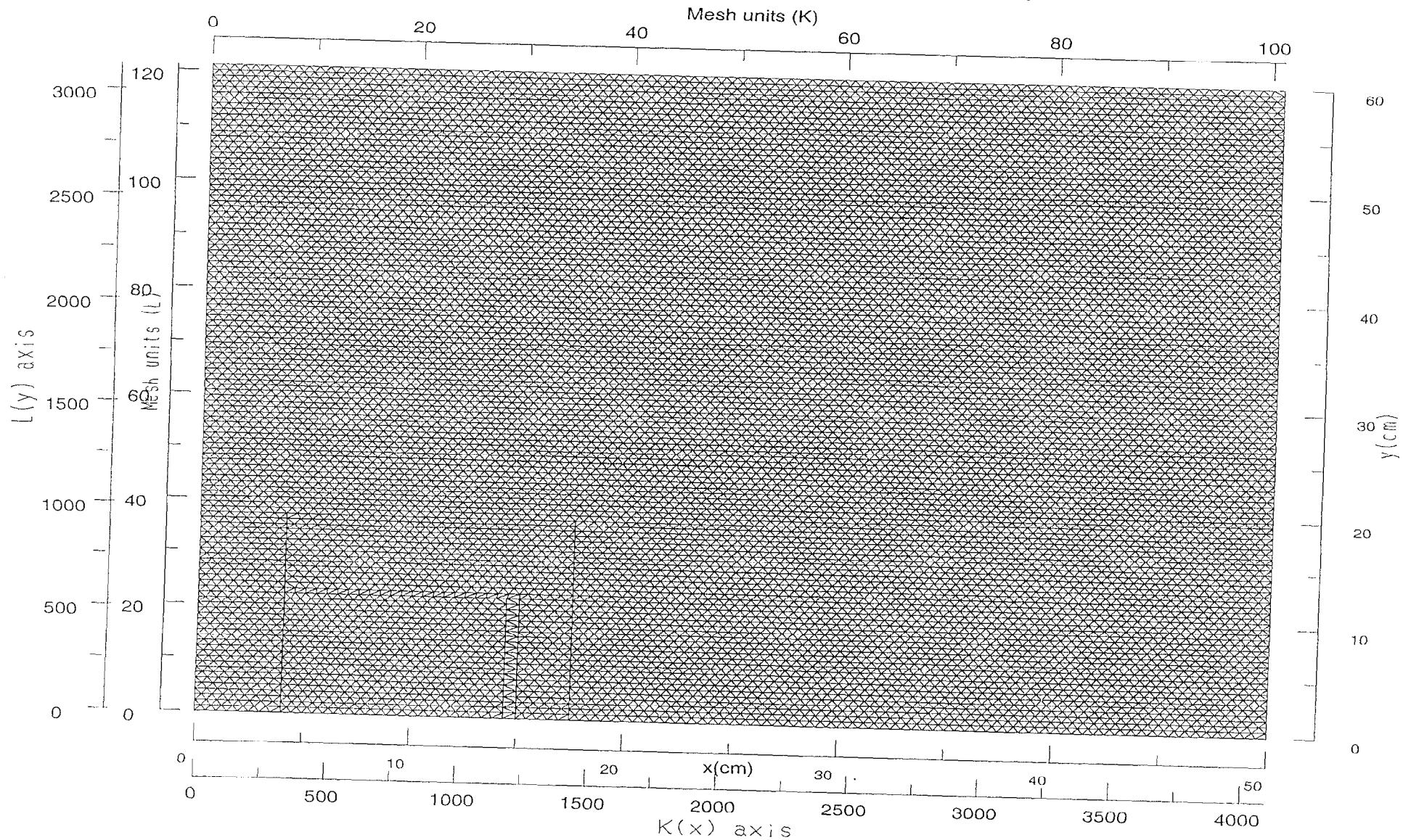
FIGURE 5) Three regions of the POISSON mesh, half the coil cross section, half the iron shield, and half the entire universe.

The axis of axial symmetry extends along the L(Y) axis.

The radial axis extends along the K(X) axis.

....

# POISSON LATTICE MESH PLOT



04/26/99 A.C.Paul

FIGURE 6) Mesh generated by the POISSON code group AUTOMESH code.

The longitudinal axis of axial symmetry extends along the L(Y) axis from the center of the solenoid.

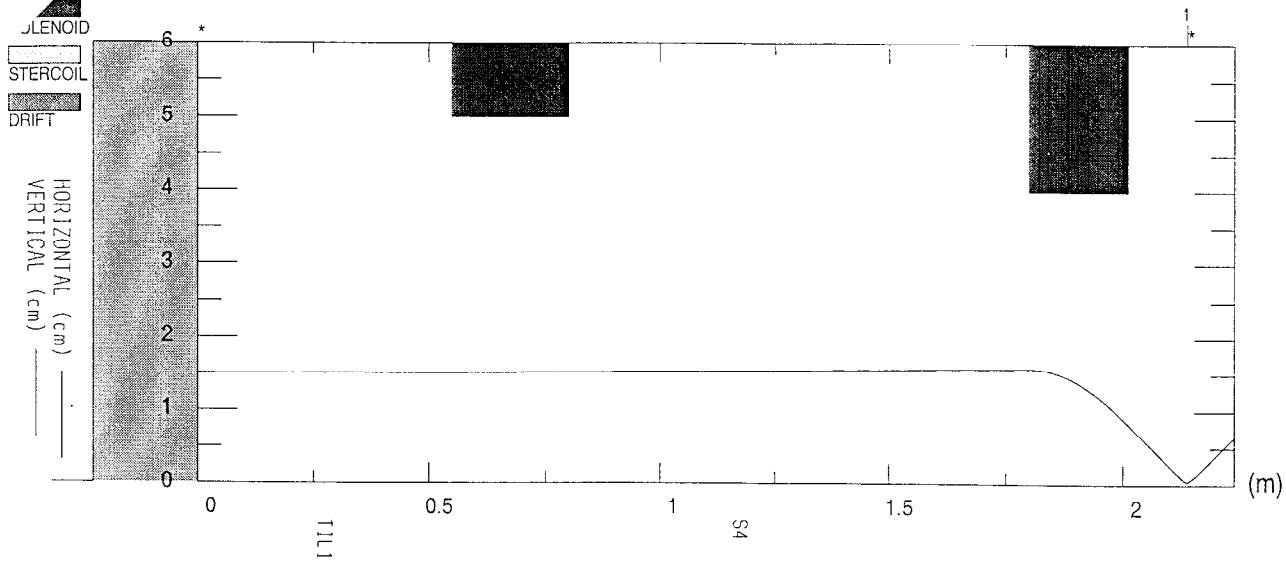
The radius is along the K(X) axis

...

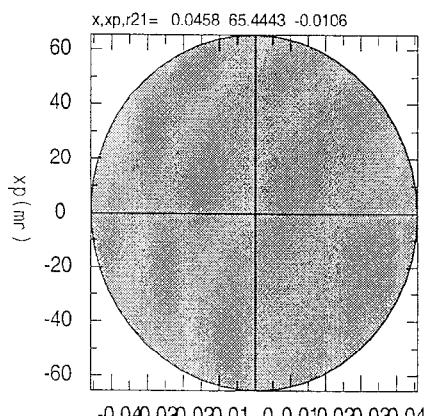
,09/00  
DC final focus solenoid optics

P = 20.5044 MeV/C  
SPC: 2000.0000 Amperes  
emit 3.000 3.000 cm-mm

Plot of the Beam Sigma Matrix 1: IO2 ( 87) LC= 2.1371m

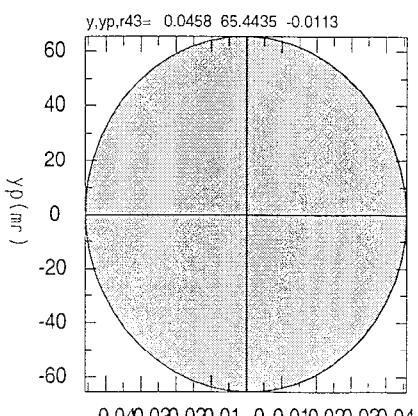


X-XP Phase Plot (0,0)



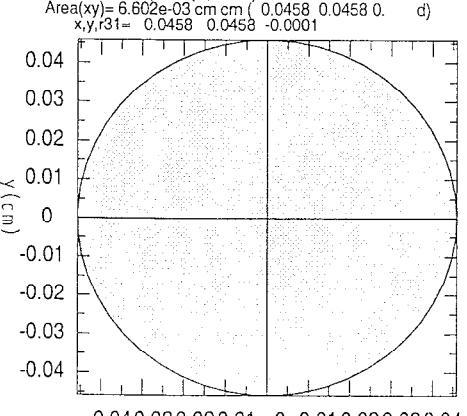
REG#: 1  
RUN#: 3 /export/work/acpaul/darht2/beamline/sff/coil4  
PLOT: 5

Y-YP Phase Plot (0,0)



data: data.optics

X-Y Beam Spot (0,0)



RUN:0013Mar at 13:54:08

Figure 9) The transport first order beam envelop profile for nominal beam parameters of 20.0 MeV, 2000 Amperes and 3.0 cm-mm emittance. Solenoids S4 and Sff run at strengths of 0 and 6.6884 kG.  
The target image is 0.12707 meters pass the magnetic exit of Sff  
line 4

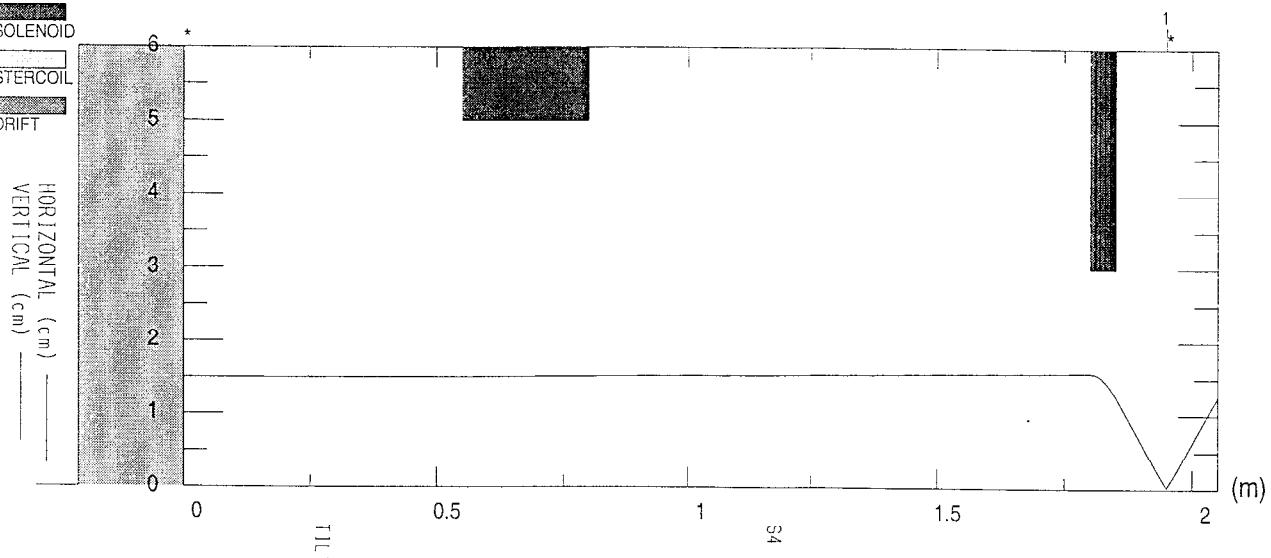
03/09/00

## pulsed final focus solenoid optics

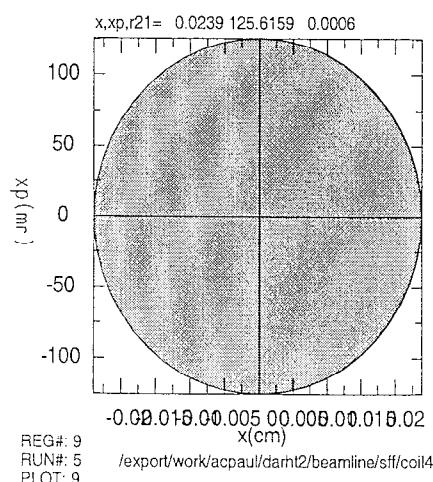
P = 20.5044 MeV/C  
SPC: 2000.0000 Amperes  
emit 3.000 3.000 cm-mm

QUAD  
BEND  
SOLENOID  
STERCOIL  
DRIFT

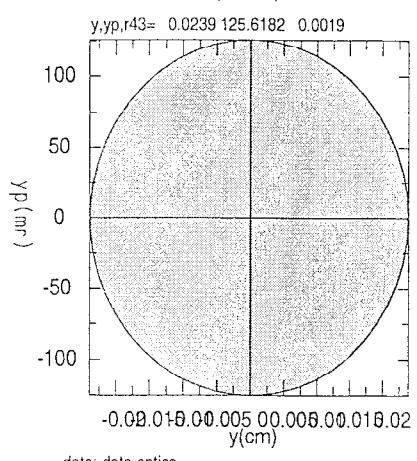
Plot of the Beam Sigma Matrix 1: IO2 ( 83) LC= 1.9500m



X-XP Phase Plot (0,0)



Y-YP Phase Plot (0,0)



X-Y Beam Spot (0,0)

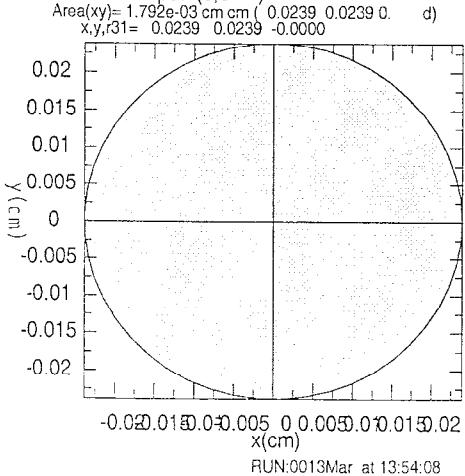


Figure 10) The transport first order beam envelop profile for the baseline final focus solenoid (Pulsed) for nominal beam parameters. Solenoids S4 and Sff run at strengths of 0 and 17.94 kG.

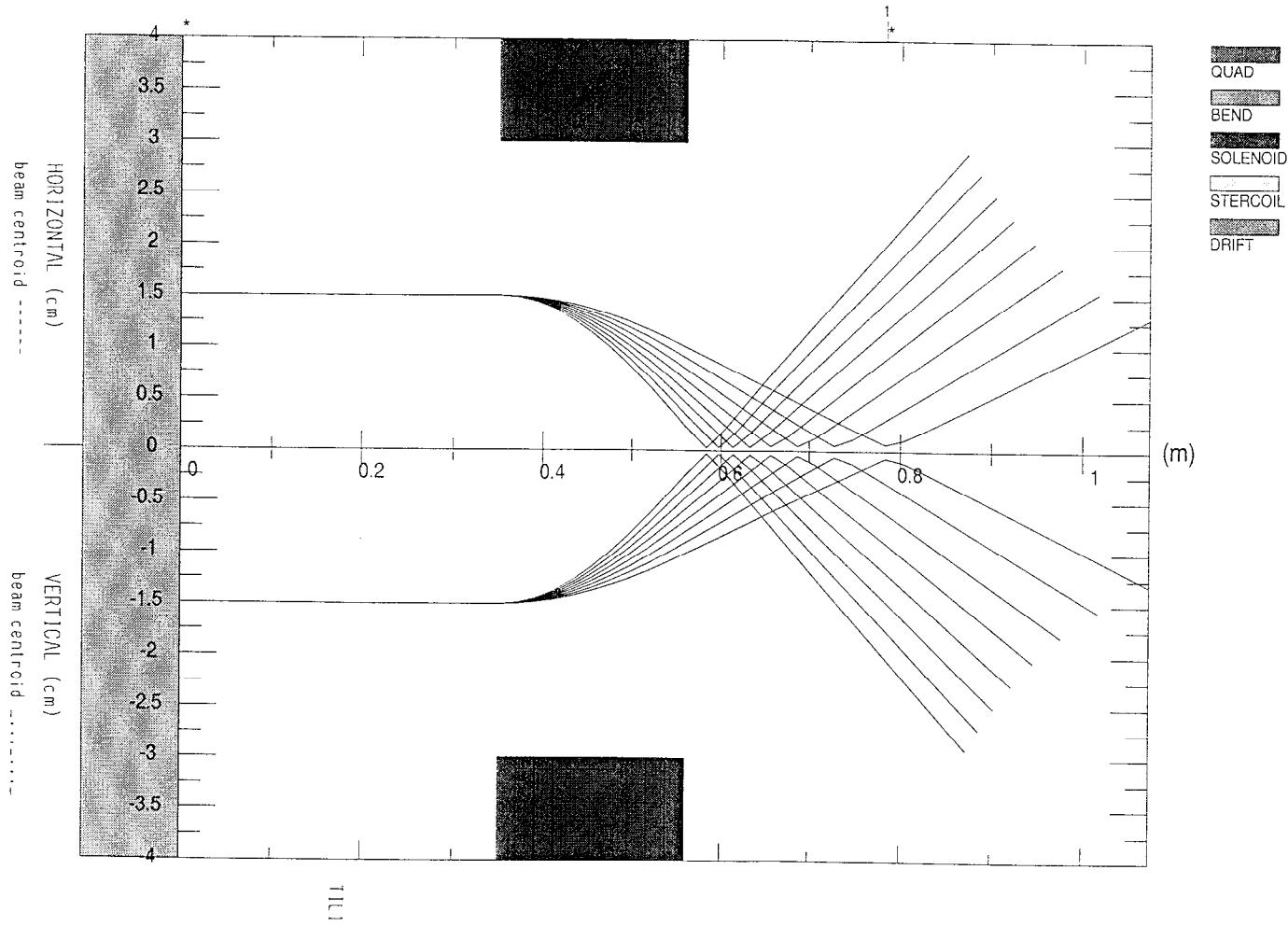
....

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02/16/00  
DARHT II DC final focus solenoid 13.88"OD

P = 20.5044 MeV/C  
SPC: 2000.0000 Amperes  
emit 3.000 3.000 cm-mm

zrange: 0. 1.0732 m



REG#: 9  
RUN#: 48 /export/work/acpaul/darht2/beamlne/sff/coil4  
PLOT: 26 data: data.tran

RUN:0013Mar at 14:29:08

Figure 11) Focusing of the beam by the final DC focus solenoid Sff. The several beam traces are for excitations of 800, 900, 1000, 1100, 1200, 1300, 1400, and 1500 Amperes.

....

....

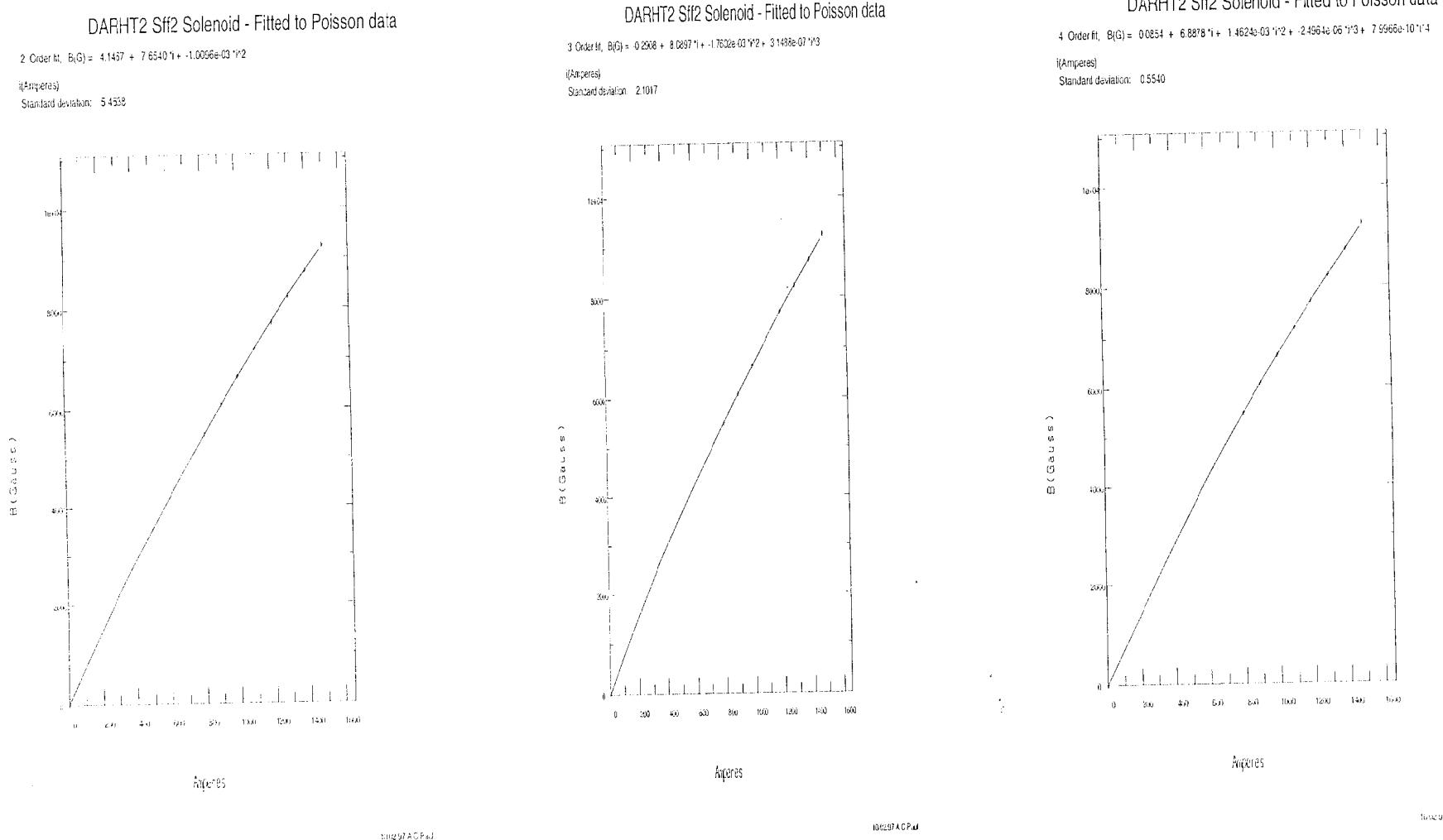
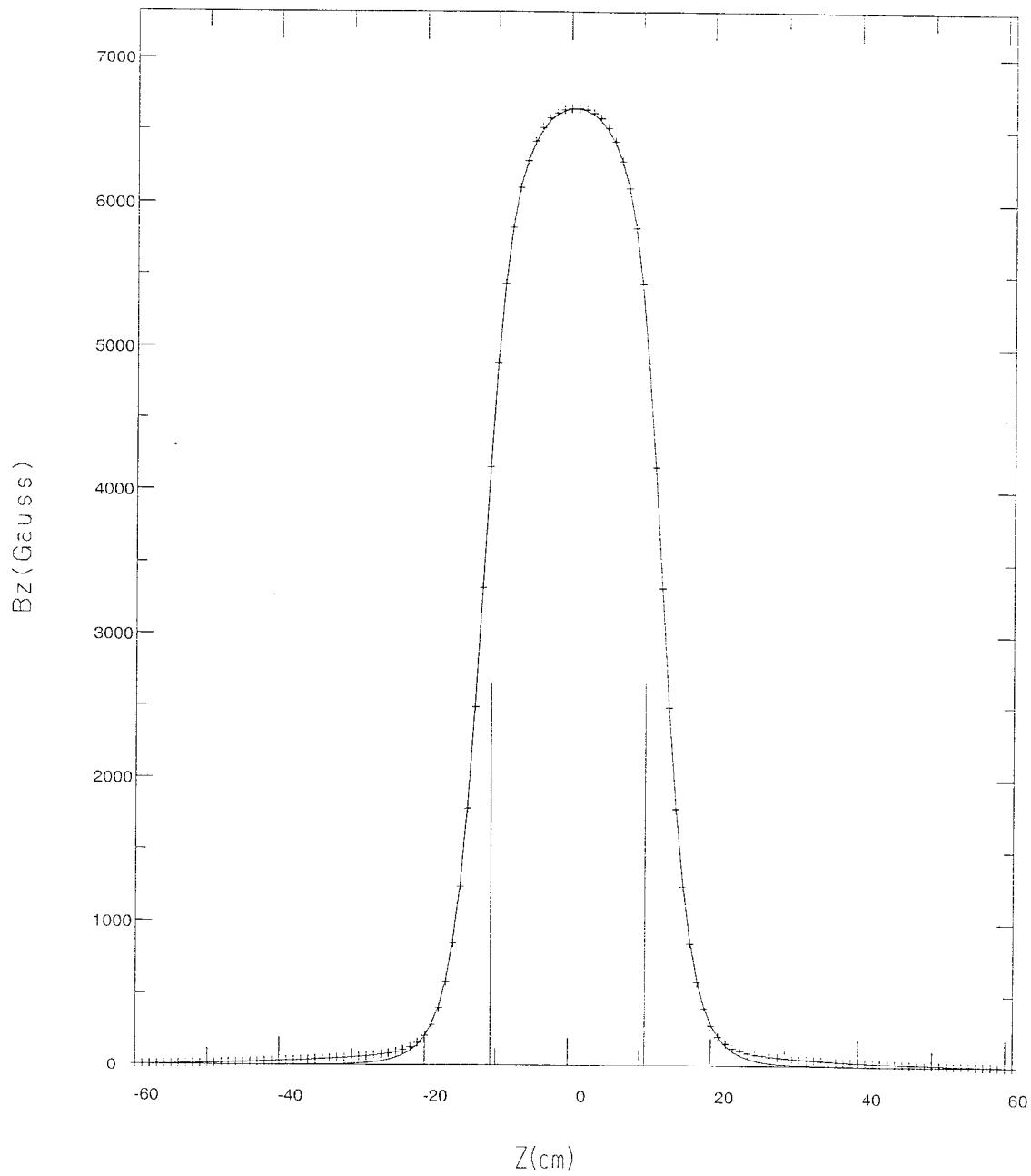


FIGURE 12) Excitation curves for DC final focus solenoid. A) fit by 2nd order polynomial, B) fit by third order polynomial, C) fit by fourth order polynomial.  
 Range of actual data extends from 800-1500 Amperes, coordinate 0,0 is assumed.

## Sff2 AXIAL MAGNETIC FIELD

1000 Amperes excitation Bz(max)=6652.797 Standard deviation: 2.2934

$B_0/(1 + b(z/a)^2 + c(z/a)^4 + d(z/a)^6 + e(z/a)^8)$  z=z-0.5 cm, shift magnet center  
 Fit: 1.4688e+01 2.3705e-01 7.4556e-02 8.1432e-01 1.7744e+00



Integral BL 1.69604e+05 G-cm B^2L 9.28717e+08 G^2-cm EffL 20.9833 cm

8/12/97 A.C.Paul

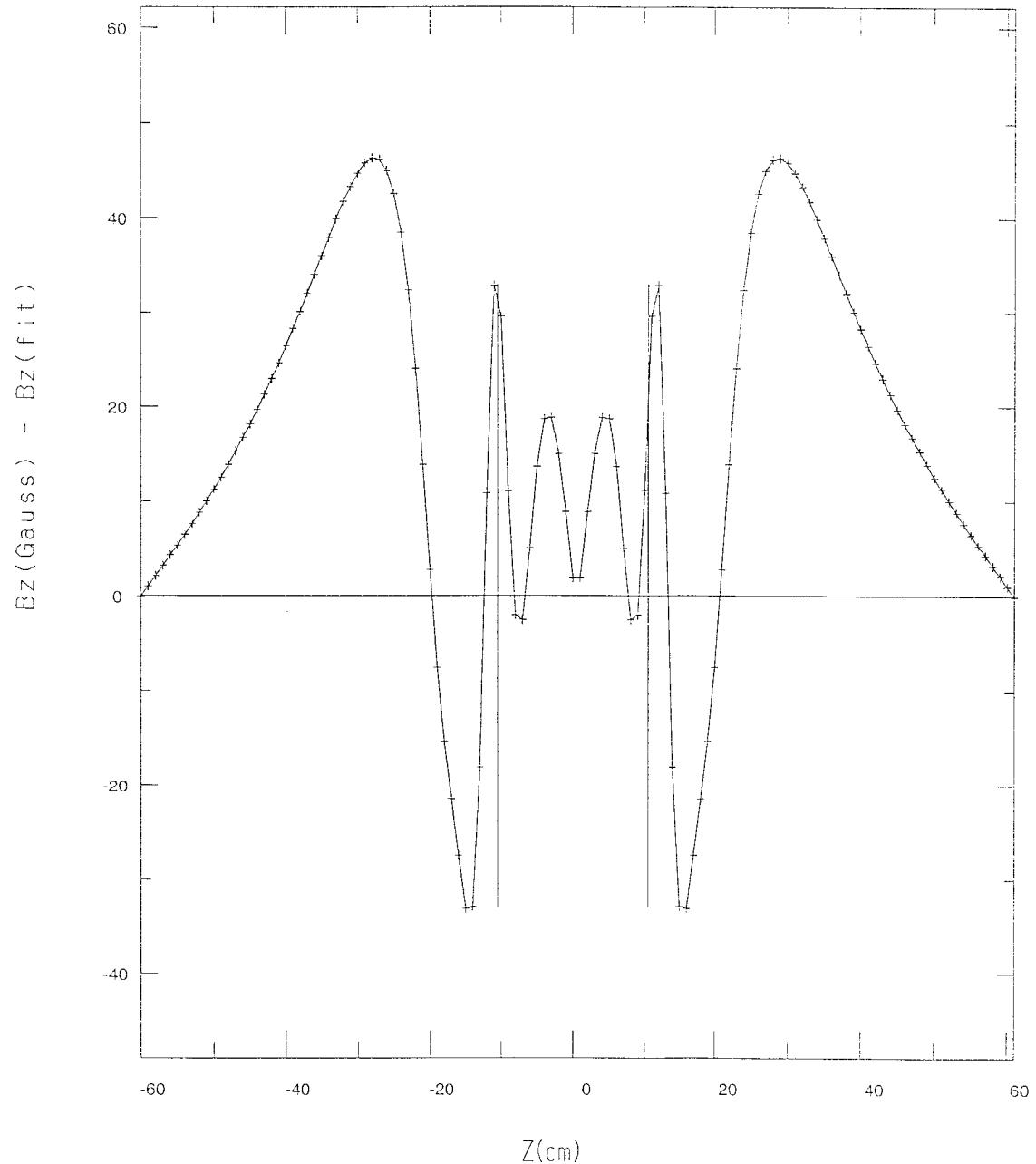
Figure 13) Fit to the axial field profile at 1000 Amperes excitation. The shape is generated by a reciprocal eighth order polynomial. The two vertical lines are markers at the magnetic entrance and exit of the lens.

....  
 ....

## Sff2 AXIAL FIX ERROR FIELD

1000 Amperes excitation Bz(max)=6652.797 Standard deviation: 2.2934

$B_0/(1 + b*(z/a)^2 + c*(z/a)^4 + d*(z/a)^6 + e*(z/a)^8)$        $z=0.5 \text{ cm, shift magnet center}$   
 Fit: 1.4688e+01 2.3705e-01 7.4556e-02 8.1432e-01 1.7744e+00



Integral BL 1.69604e+05 G-cm B^2L 9.28717e+08 G^2-cm EffL 20.9833 cm  
 error rang -33.112 46.310 |z|<30.0 cm

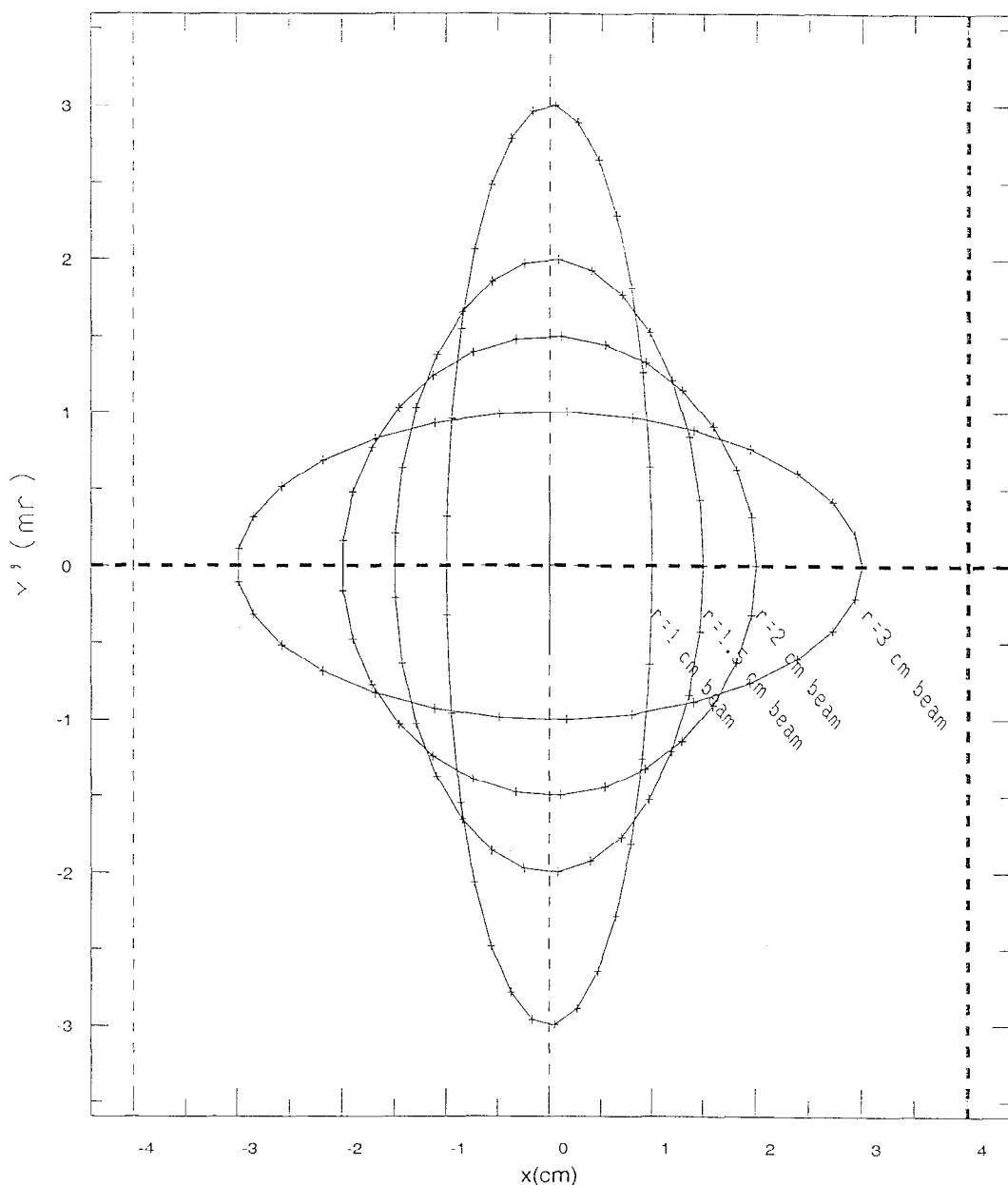
8/12/97 A.C.Paul

Figure 14) Difference between the fitted field profile at 1000 Amperes excitation and the POISSON code calculated field points. The two vertical lines are markers at the magnetic entrance and exit of the lens.

....

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## Initial Phase Space - TRAJ data



/export/work/acpaul/darht2/beamline/sff/coil4  
data.traj3

13-Mar-00

A.C.Paul  
13-Mar-00

Figure 15) Transverse phase space for beam radius of 1.0, 1.5, 2.0, and 3.0 cm and nominal parameters of 20 MeV 3 cm-mr emittance. Points on these bounding ellipsoids are used by the Trajectory code to evaluate the chromatic and spherical aberrations.

....

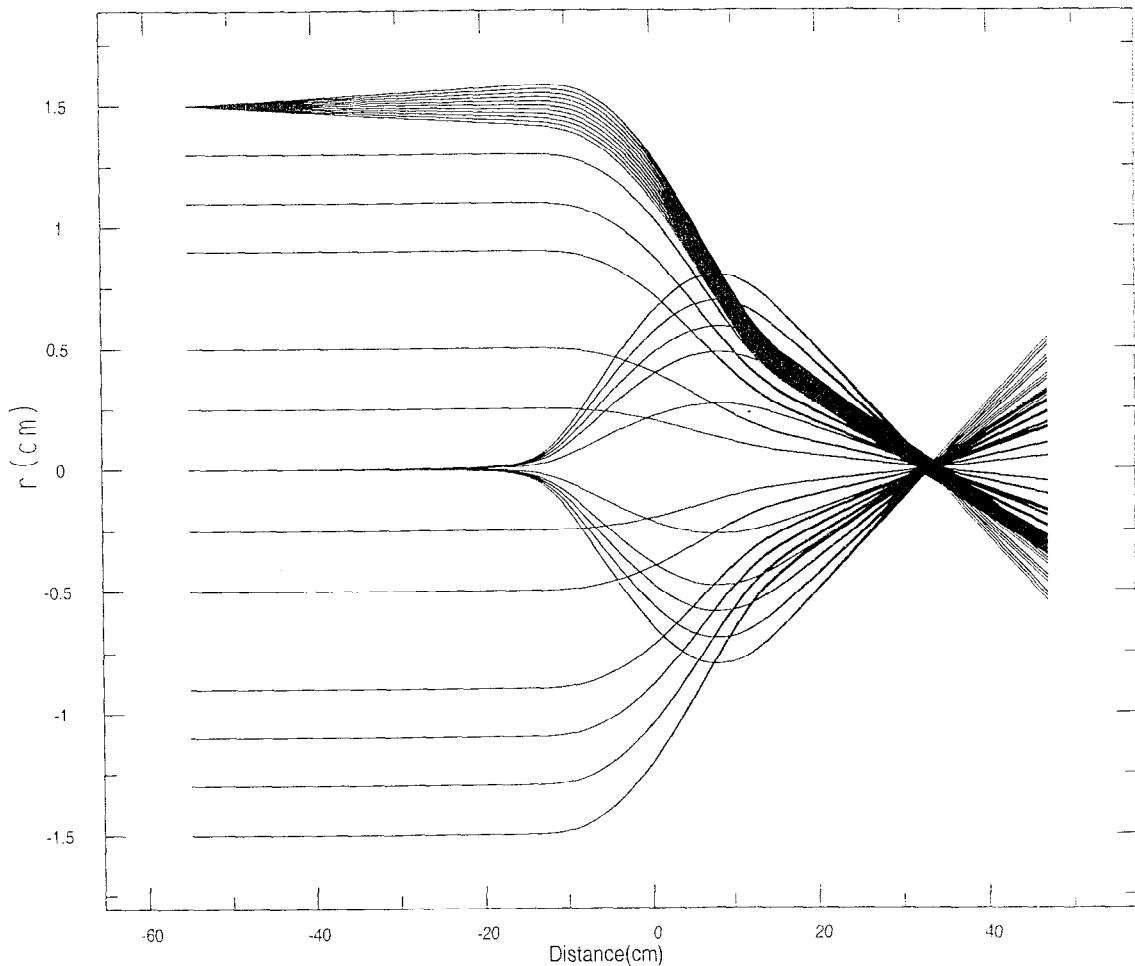
## Spherical and Chromatic Aberration

800.0 0.081948 33.22925 Amps, rmin, zloc

Sff run at 800.0 Amperes

Minimum spot 0.081948 cm

Located at 33.22925 cm



/export/work/acpaul/damit2/beamline/sff/coil4  
[temp]

1-Mar-00

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1-Mar-00

Figure 16) TRAJ code orbits for particle load along the x and y axis on a 0.25 cm grid. Orbits at  $+X=1.5$  cm have an angular distribution of  $\pm 2.0$  mr. These orbits are defined with energies of 19.8, 20.0, and 20.2 MeV. Note that the orbits distributed along the Y axis at  $X=0$  rotate into the x plane as they pass through the focusing lens centered at  $Z=0$ . The thickening of the lines toward the right of the plot is the effect of the energy spread, dispersed by the chromatic aberration of the final lens.

## Spherical and Chromatic Aberration

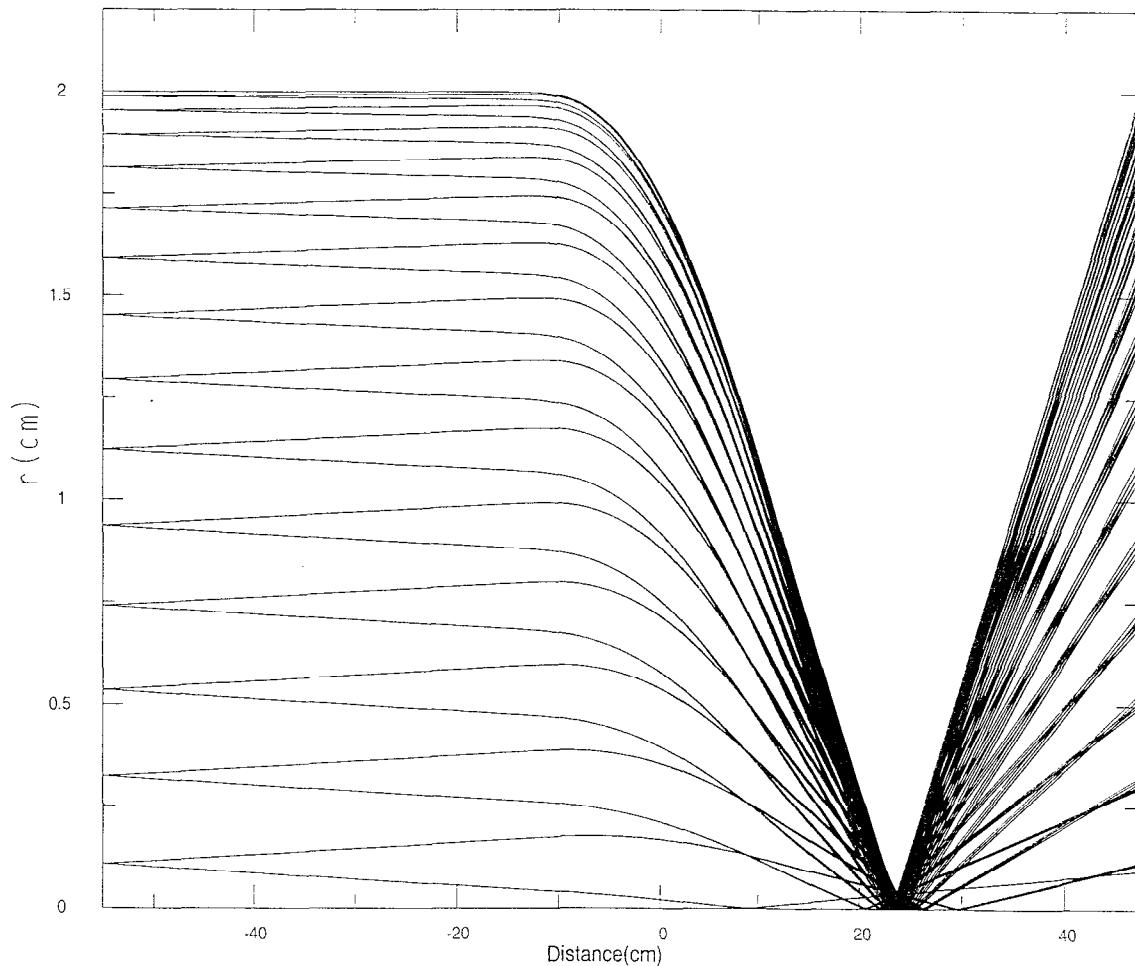
Initial Beam Radius: 2.0000 cm

+0.5 Percent energy spread.

Sff run at 1000.0 Amperes

Minimum spot 0.046955 cm

Located at 23.58072 cm



/export/work/acpaul/darht2/beamline/sff/coil4  
.tempj3

3-Mar-00

A.C.Paul  
3-Mar-00

Figure 17) TRAJ code orbits distributed in the phase space shown in figure 15.

Plotted here is the radius vs longitudinal position, with the final focus lens centered at  $Z=0$ .

imaging the beam at about 23 cm. The phase space points are run at energy deviations of  $-0.5, 0, +0.5\% dE/E$

....

....

## Spherical and Chromatic Aberration

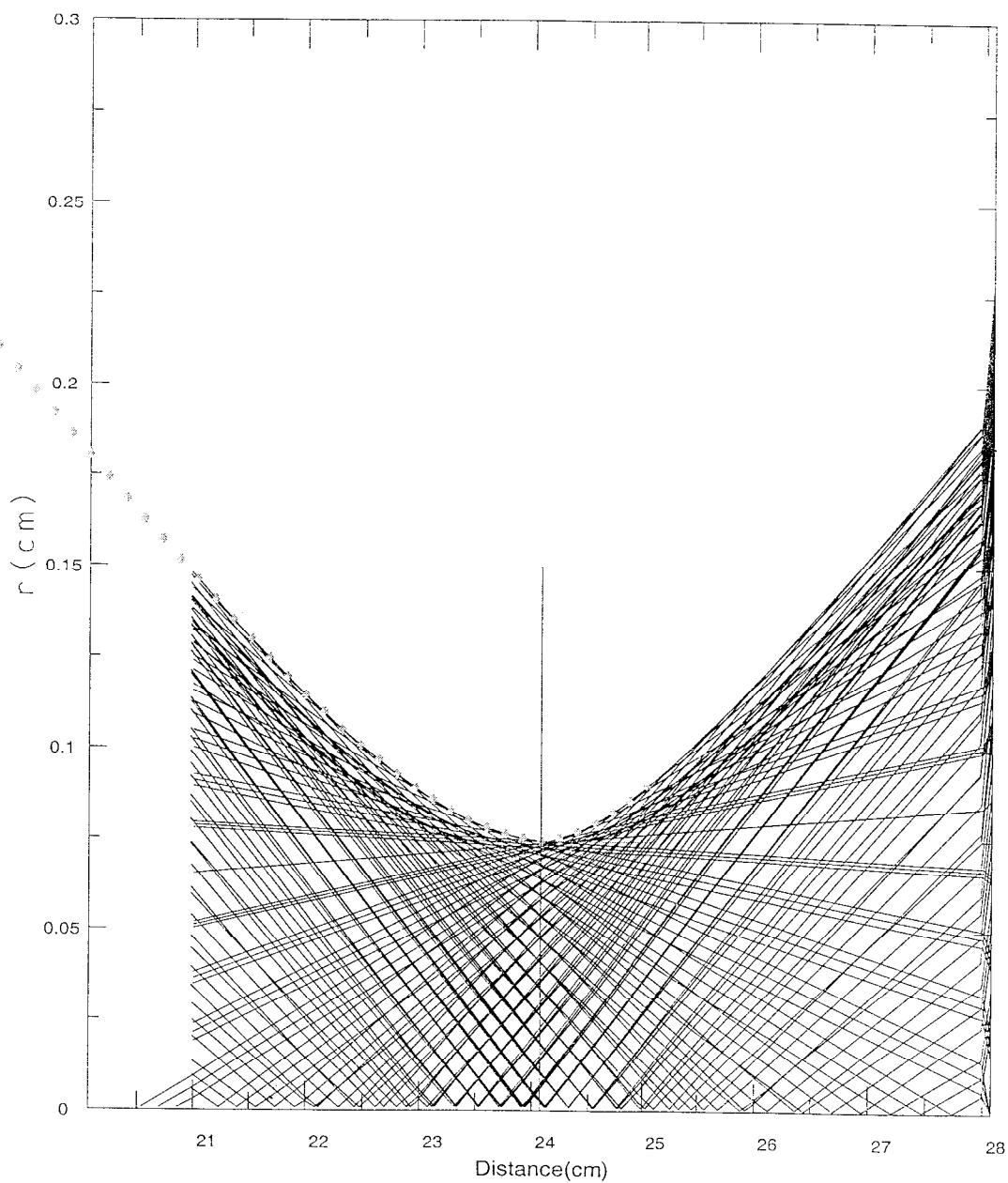
Initial Beam Radius: 1.0000 cm

+0.5 Percent energy spread.

Sff run at 1000.0 Amperes

Minimum spot 0.074216 cm

Located at 24.07356 cm



/export/work/acpaul/darht2/beamline/sff/coil4  
.tempj3

3-Mar-00

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3-Mar-00

Figure 18) Expanded zone around image, for an initial beam radius of 1.0 cm +0.5% dE/E  
The image point is located at 24.07 cm

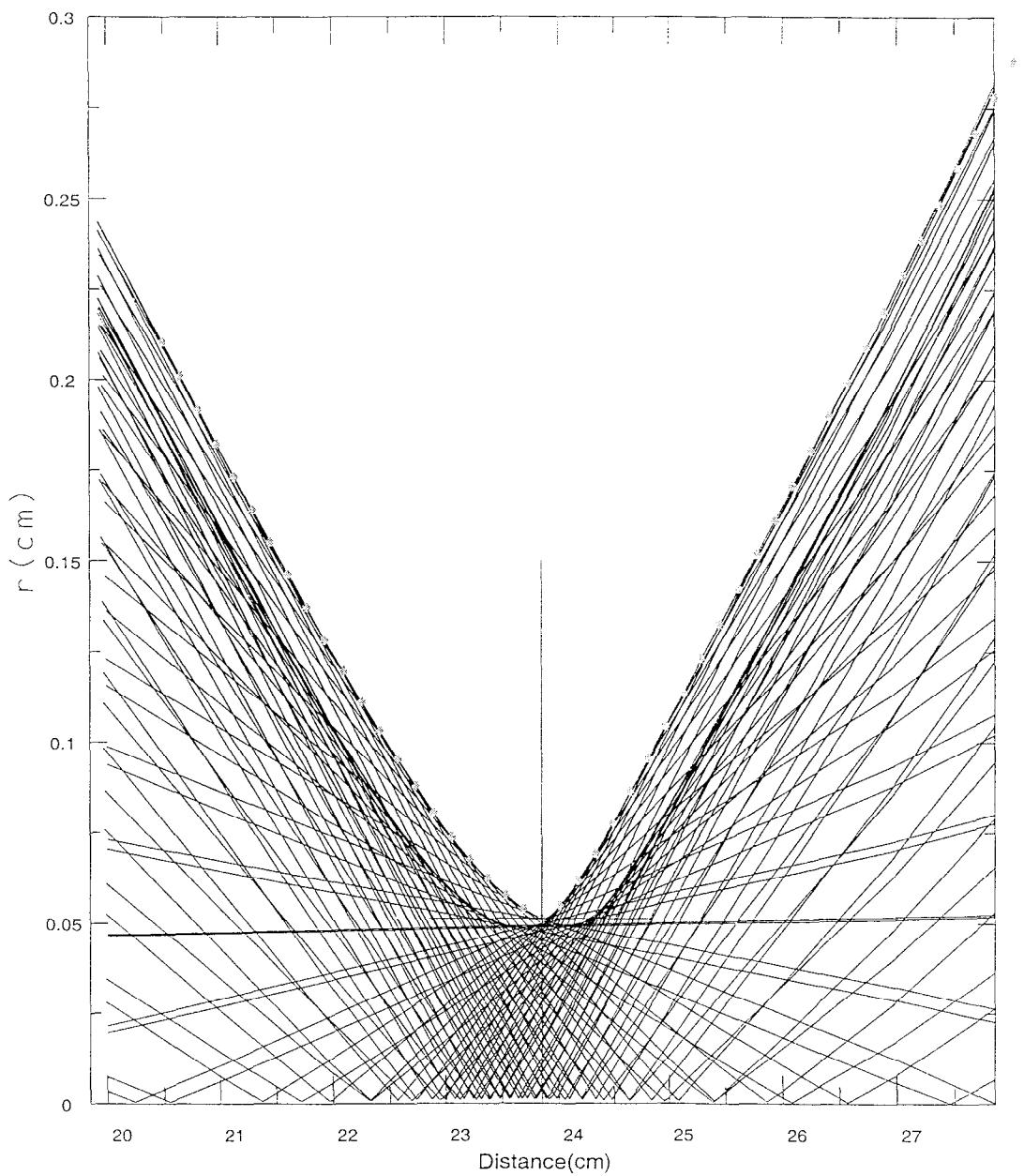
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....

## Spherical and Chromatic Aberration

Initial Beam Radius: 1.5000 cm  
Sff run at 1000.0 Amperes  
Minimum spot 0.051143 cm  
Located at 23.85145 cm

+0.5 Percent energy spread.



/export/work/acpaul/darht2/beamline/sff/coil4  
.tempj3

6-Mar-00

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Figure 19) Expanded zone around image, for an initial beam radius of 1.5 cm +0.5% dE/E  
The image point is located at 23.85 cm

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## Spherical and Chromatic Aberation

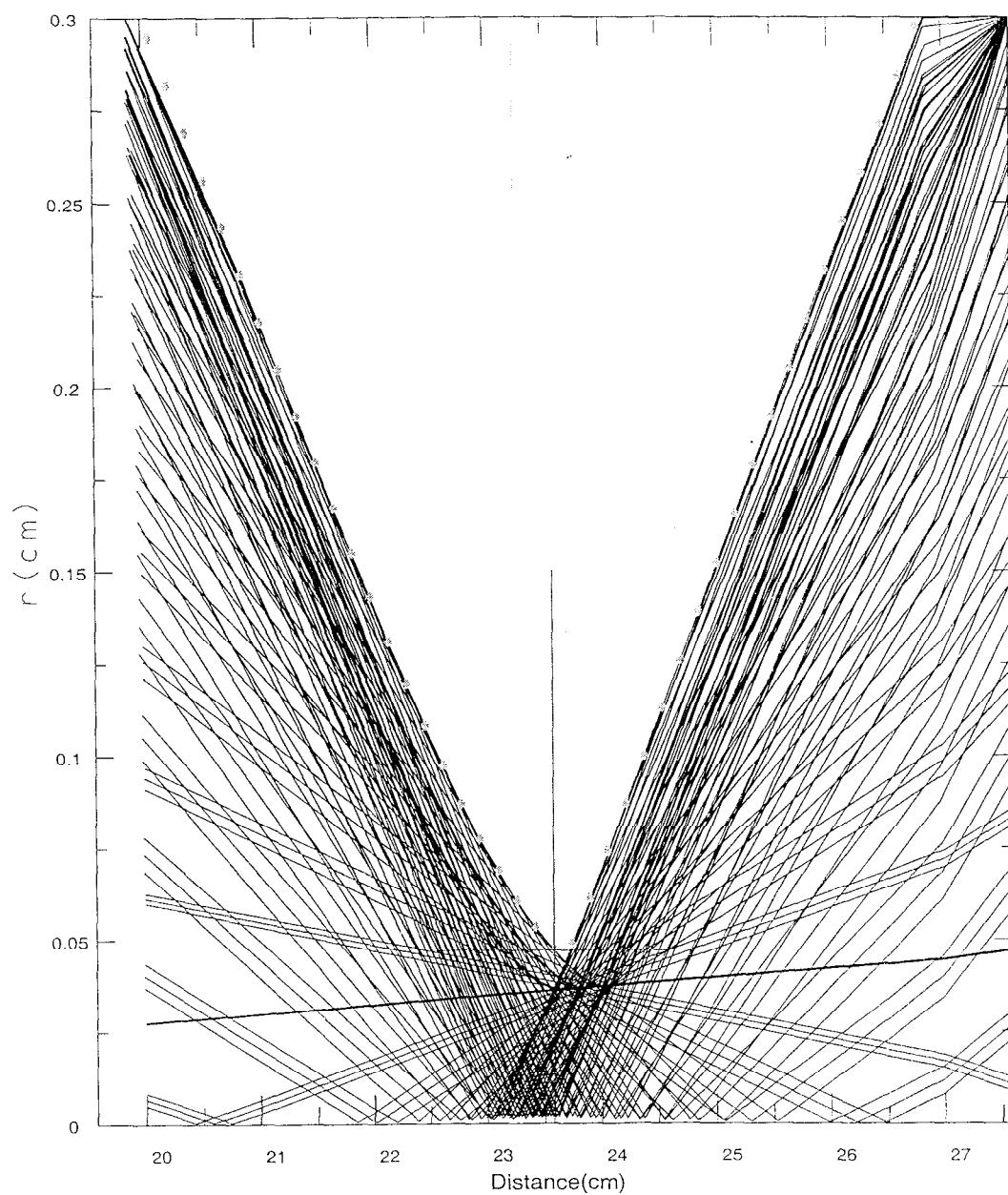
Initial Beam Radius: 2.0000 cm

+0.5 Percent energy spread.

Sff run at 1000.0 Amperes

Minimum spot 0.046955 cm

Located at 23.58072 cm



/export/work/acpaul/darht2/beamline/sff/coil4  
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3-Mar-00

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Figure 20) Expanded zone around image, for an initial beam readius of 2.0 cm +0.5% dE/E  
The image point is located at 23.58 cm

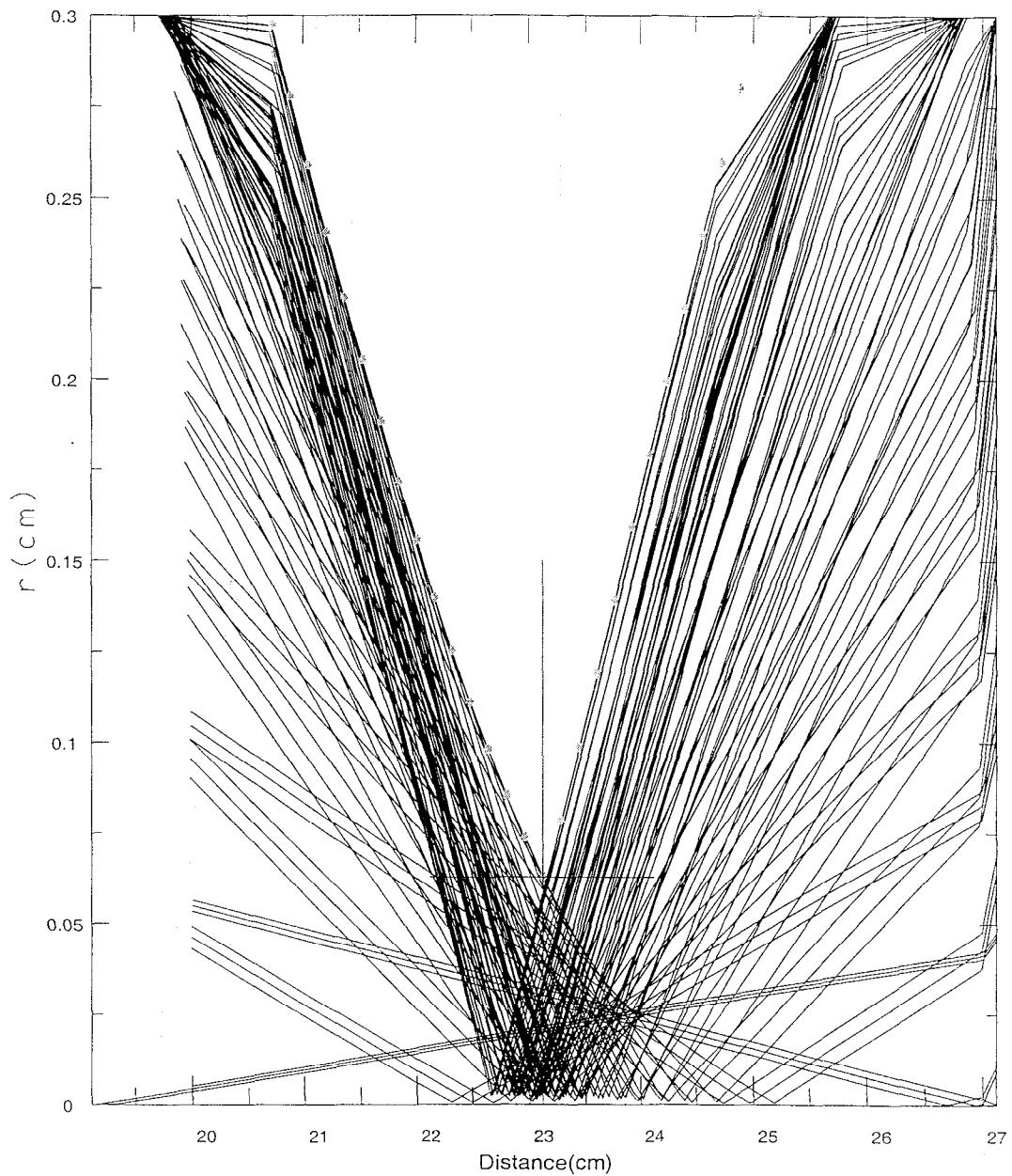
....

....

## Spherical and Chromatic Aberation

Initial Beam Radius: 3.0000 cm  
Sff run at 1000.0 Amperes  
Minimum spot 0.062765 cm  
Located at 23.11822 cm

+/-0.5 Percent energy spread.



/export/work/acpaul/darht2/beamline/sff/coil4  
.tempj3

3-Mar-00

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3-Mar-00

Figure 21) Expanded zone around image, for an initial beam radius of 3.0 cm +/-0.5% dE/E  
The image point is located at 23.12 cm. Note the shorting of the focal length with the larger  
initial beam radius loads.  
....

## DARHT2 - 13.88" DC FINAL FOCUS SOLENOID Sff2

Initial beam  $r, r', \text{tilt} = 1.0, 3.0, 0.$

Drift distance to SFF = 0.55 meters

7.0, 2.5cm iron shroud, 37cm long, 8cm ID, 35cm OD

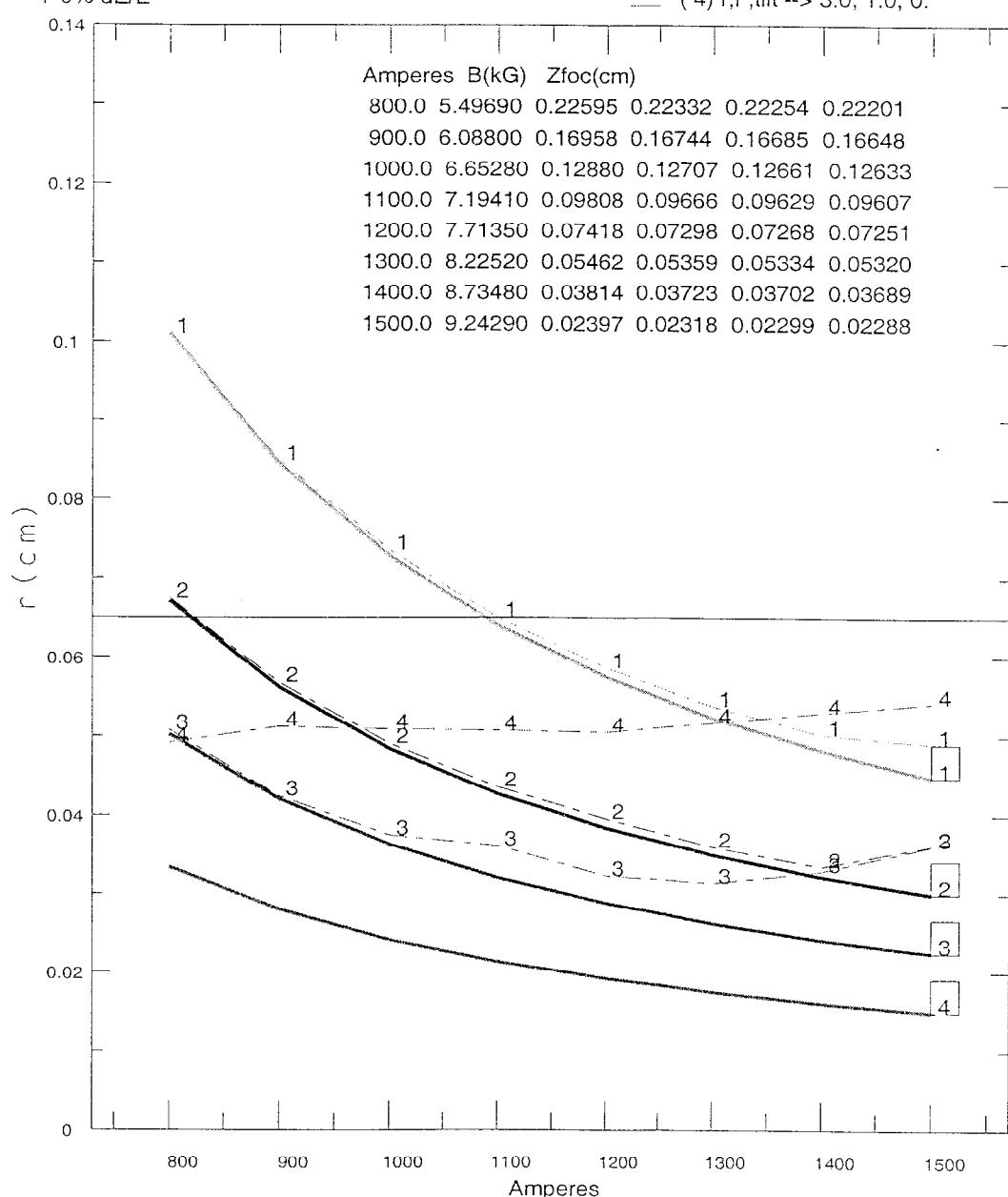
$\pm 0\%$  dE/E

( 1)  $r, r', \text{tilt} \rightarrow 1.0, 3.0, 0.$

( 2)  $r, r', \text{tilt} \rightarrow 1.5, 2.0, 0.$

( 3)  $r, r', \text{tilt} \rightarrow 2.0, 1.5, 0.$

( 4)  $r, r', \text{tilt} \rightarrow 3.0, 1.0, 0.$



/export/work/acpaul/darht2/beamlne/sff/coil4  
temps

13-Mar-00

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Figure 22) Summary of chromatic and spherical aberrations, 0% dE/E

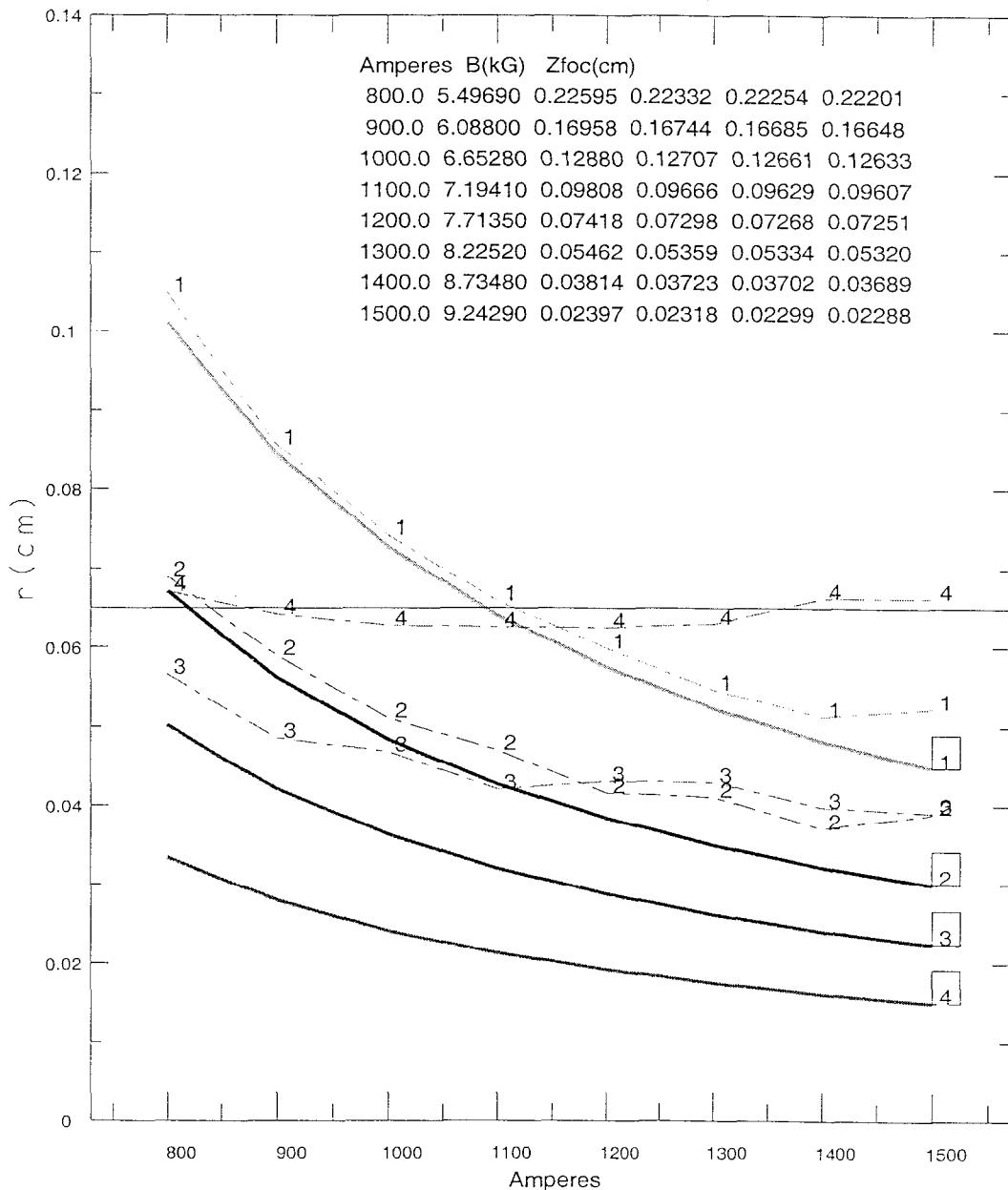
Initial particle loads of 1.0, 1.5, 2.0, and 3.0 cm and emittance of 3.0 cm-mr, figure 15.

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## DARHT2 - 13.88" DC FINAL FOCUS SOLENOID Sff2

Initial beam  $r, r', \text{tilt}$  = 1.0, 3.0, 0.  
 Drift distance to SFF = 0.55 meters  
 7.0, 2.5cm iron shroud, 37cm long, 8cm ID, 35cm OD  
 $\pm 1/2\% \text{ dE/E}$



/export/work/acpaul/darht2/beamline/sff/coil4  
 temps

13-Mar-00

A.C.Paul  
 13-Mar-00

Figure 23) Summary of chromatic and spherical aberrations, 0.5% dE/E  
 Initial particle loads of 1.0, 1.5, 2.0, and 3.0 cm and emittance of 3.0 cm-mr, figure 15.

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 ....

## DARHT2 - 13.88" DC FINAL FOCUS SOLENOID Sff2

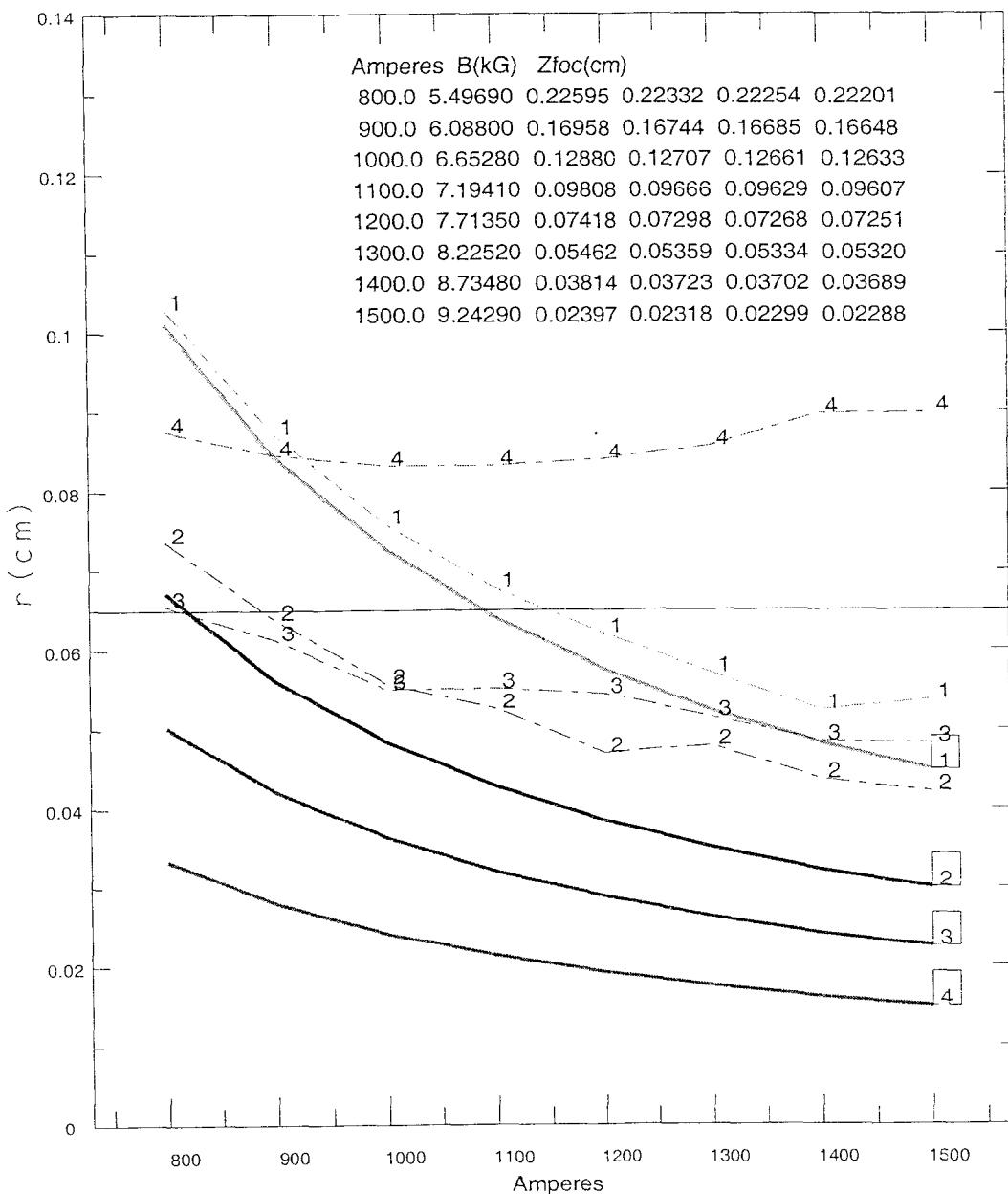
Initial beam  $r, r', \text{tilt} = 1.0, 3.0, 0.$

Drift distance to SFF = 0.55 meters

7.0, 2.5cm iron shroud, 37cm long, 8cm ID, 35cm OD

$\pm 1.0\% dE/E$

- (1)  $r, r', \text{tilt} \rightarrow 1.0, 3.0, 0.$
- (2)  $r, r', \text{tilt} \rightarrow 1.5, 2.0, 0.$
- (3)  $r, r', \text{tilt} \rightarrow 2.0, 1.5, 0.$
- (4)  $r, r', \text{tilt} \rightarrow 3.0, 1.0, 0.$



/export/work/acpaul/darht2/beamline/sff/coil4  
temps

13-Mar-00

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13-Mar-00

Figure 24) Summary of chromatic and spherical aberrations, 1.0%  $dE/E$   
Initial particle loads of 1.0, 1.5, 2.0, and 3.0 cm and emittance of 3.0 cm-mr, figure 15.

....  
....

## DARHT2 - 13.88" DC FINAL FOCUS SOLENOID Sff2

Initial beam  $r, r', \text{tilt} = 1.0, 3.0, 0.$

Drift distance to SFF = 0.55 meters

7.0, 2.5cm iron shroud, 37cm long, 8cm ID, 35cm OD

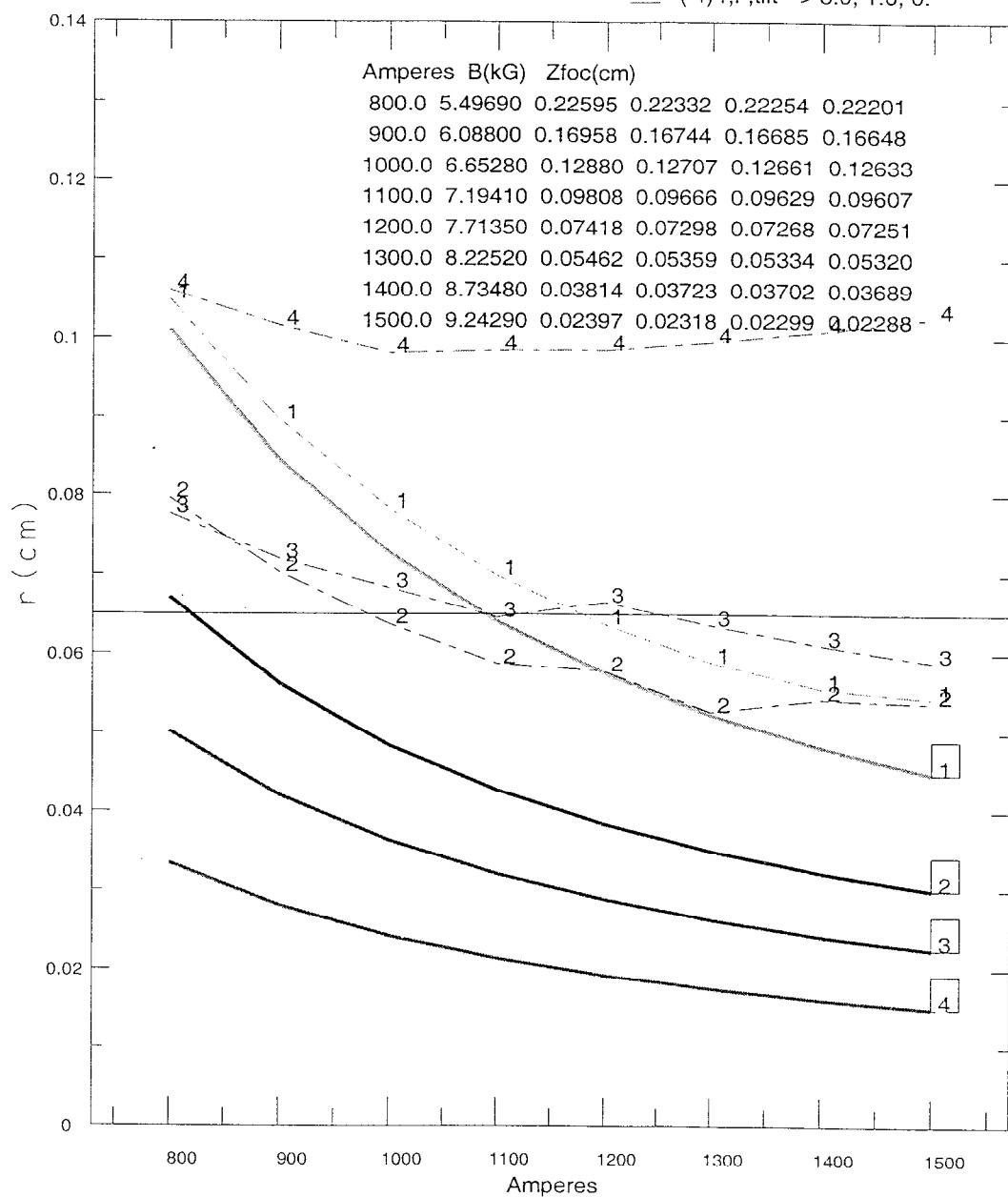
$\pm 1.5\% dE/E$

( 1)  $r, r', \text{tilt} \rightarrow 1.0, 3.0, 0.$

( 2)  $r, r', \text{tilt} \rightarrow 1.5, 2.0, 0.$

( 3)  $r, r', \text{tilt} \rightarrow 2.0, 1.5, 0.$

( 4)  $r, r', \text{tilt} \rightarrow 3.0, 1.0, 0.$



/export/work/acpaul/darht2/beamline/stf/coil4  
temps

13-Mar-00

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13-Mar-00

Figure 25) Summary of chromatic and spherical aberrations, 1.5% dE/E

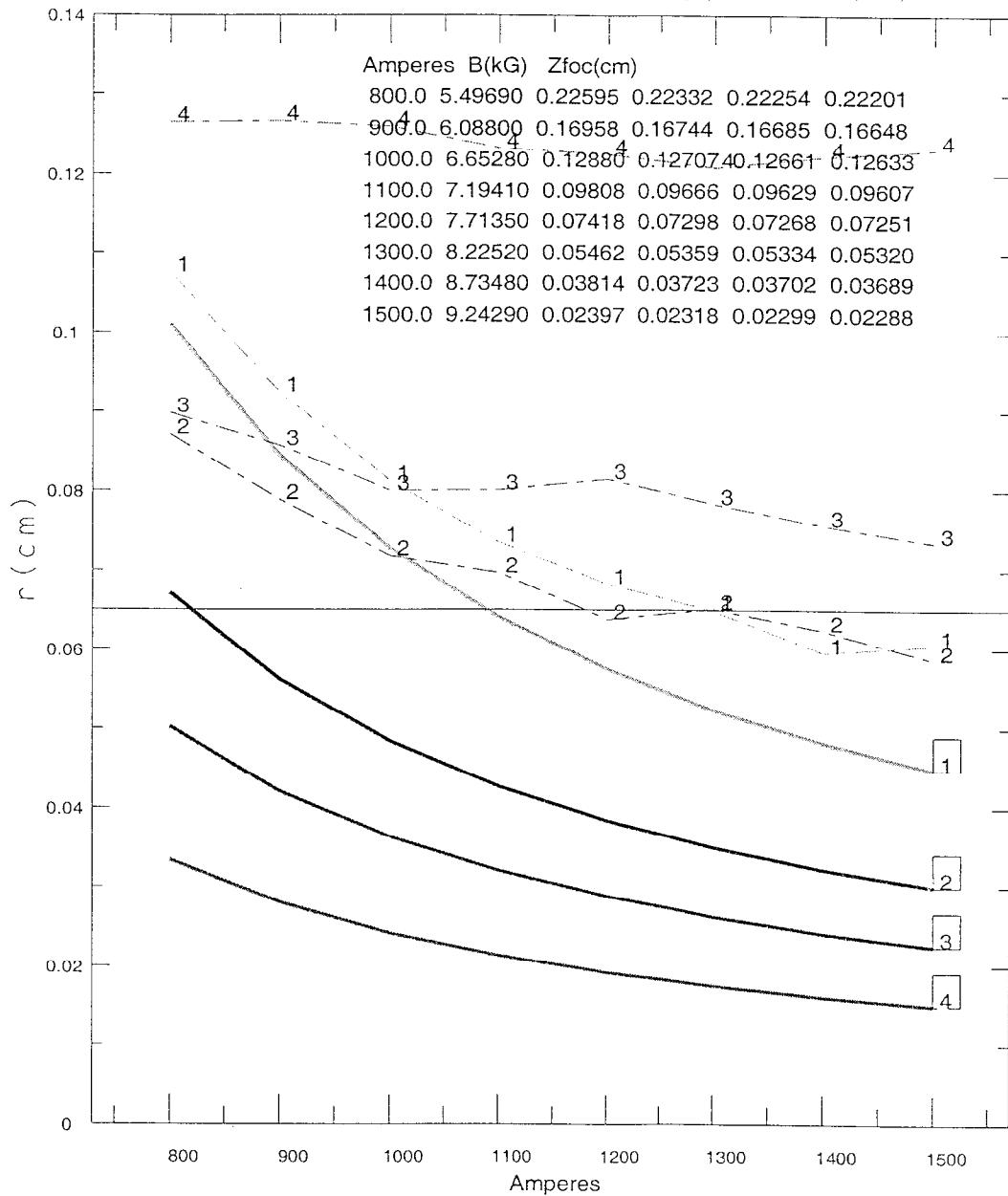
Initial particle loads of 1.0, 1.5, 2.0, and 3.0 cm and emittance of 3.0 cm-mr, figure 15.

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## DARHT2 - 13.88" DC FINAL FOCUS SOLENOID Sff2

Initial beam  $r, r', \text{tilt} = 1.0, 3.0, 0.$   
 Drift distance to SFF = 0.55 meters  
 7.0, 2.5cm iron shroud, 37cm long, 8cm ID, 35cm OD  
 $\pm 2.0\% \text{ dE/E}$



/export/work/acpaul/darht2/beamline/sff/coil4  
 temps

13-Mar-00

A.C.Paul  
 13-Mar-00

Figure 26) Summary of chromatic and spherical aberrations, 2.0% dE/E  
 Initial particle loads of 1.0, 1.5, 2.0, and 3.0 cm and emittance of 3.0 cm-mr, figure 15.

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